Geophysical Information for Teachers (GIFT) Workshop

Hot Topics in Earth Space Science!

December 14-15, 2015

San Francisco Marriott Marquis

Room Golden Gate A

Agenda and Bios

AGU-NESTA Geophysical Information For Teachers (GIFT) Workshop 2015
<u>Hot Topics in Earth and Space Science!</u>

Marriott Marquis, Golden Gate A

Monday, December 14

7:30 – 8:00 BREAKFAST

8:00 – 8:05 **Welcome from AGU** – Bethany Adamec, AGU Education and Public Outreach Coordinator

8:05 – 8:10 **Welcome from NESTA** – Carla McAuliffe, Executive Director, NESTA

8:10 – 8:15 **Logistics** – Bethany Adamec, AGU Education and Public Outreach Coordinator

8:15 – 9:45 ***From ship to shore: Communications from the front lines of marine debris research*** – Mary Engels (University of Idaho) and Laura Nelson (Sea Education Association)

9:45 – 10:00 BREAK

10:00 – 11:30 ***Searching for Earth's Twin: NASA's Kepler Mission--1,000 Exoplanets and Counting*** – Edna DeVore (SETI Institute) and Alan Gould (Lawrence Hall of Science)

11:30 – 12:15 LUNCH

12:30 – 1:30 **TOWN HALL:** ***Next Steps for the Next Generation Science Standards in Earth and Space Science: A Town Hall Discussion*** – Aida Awad (Maine Township High School), Susan Sullivan (CIRES/CU Boulder), and Edward Robeck (AGI) **Moscone West 2007**

1:45 – 3:15 ***Conserving our nonrenewable resources: Developing a theme-based NGSS-aligned integrated science unit using the Mi-STAR method*** – Emily Gochis, Stephanie Tubman, Luke Bowman, Steve Mattox, Doug Oppliger, and Robert Handler (Michigan Technological University – MiSTAR Program)

3:15 – 3:30 Discussion, Closing for Day 1

3:30 Adjourn for Exhibits, Meeting

4:00 – 6:00 Optional Field Trip – ***A Ramble through San Francisco's Geology***– Dr. John Karachewski (EPA) - meet in lobby of Moscone South near luggage check-in.

Tuesday, December 15

7:30 – 8:00 BREAKFAST

8:00 – 8:10 Overview of Plans for Day 2, Logistics - Bethany Adamec, AGU Education and Public Outreach Coordinator

8:10 – 9:40 ***Tracking Change over Time: Earth Imagery in the Classroom*** – Thomas Adamson (SGT Inc.) and Naga Manohar Velpuri (ASRC InuTeq LLC.)

9:40 – 10:00 Break

10:00 – 11:30 ***Teaching Mineral Resources with an Emphasis on the NGSS Practices and Crosscutting Concepts*** – Aida Awad (Maine East High School), Susan M. Sullivan (University of Colorado), and Edward Robeck (AGI)

11:30 – 12:15 LUNCH

12:15 – 1:15 **Share-A-Thon**

1:15 – 2:45 ***The Science of Fracking*** – Gregory Lackey (University of Colorado Boulder), Lisa Gardiner (UCAR Center for Science Education), and Daniel Birdsell (University of Colorado Boulder)

2:45 – 3:00 Discussion, Closing, Next Steps

3:00 – 3:20 Workshop Evaluation

3:45 Optional - ***Special Presentation for GIFT Registrants at the NASA HyperWall*** – Cassie Soeffing (IGES) and NASA scientists from the Earth Science Division, Planetary Science Division, and Heliophysics Division. See the latest scientific research, geared towards educators, in a visually dynamic way on the NASA HyperWall in the Exhibit Hall.

Speaker and Presenter Biographies

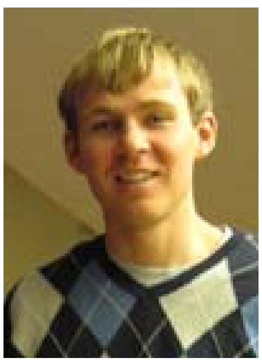
Bethany Holm Adamec

Bethany Holm Adamec is a biologist and science education specialist with a particular interest in marine science and hands-on science education for learners of all ages. Bethany is AGU's New Education and Public Outreach Coordinator. Prior to joining AGU, she was a Science Education Analyst at the National Science Foundation (NSF). Among her activities there were managing and analyzing critical data for undergraduate education programs, coordinating logistical arrangements for professional meetings, leading hands- on science lessons for preschoolers at NSF's Child Development Center, and working across the Foundation with all levels of support staff and management on the Climate Change Education Partnership Program. Her accomplishments during her time at NSF included a Director's Award for Collaborative Integration as a member of the Climate Change Education Working Group. Prior to joining NSF, Bethany taught undergraduate biology labs at American University and was a member of a team of teachers for a summer marine biology field course in Florida for a Washington, DC-based college preparatory school. Before coming to Washington, DC for graduate school, she worked for seven years for Allied Whale, a nonprofit marine mammal research group based in Bar Harbor, ME. Her activities there included assisting in the curation of the Antarctic Humpback Whale Catalog, which identifies and tracks the life history of individual humpback whales in the southern hemisphere. She has traveled to Antarctica, Hawaii, and the Gulf of Maine to study large whales. Bethany earned her B.A. in Human Ecology with a concentration in Marine Mammalogy from College of the Atlantic in Bar Harbor, ME and her M.A. in Biology with a concentration in Marine Mammal Population Genetics from American University in Washington, DC. In addition to her passion for science education, Bethany enjoys hiking, gardening, and training and showing dogs in performance events.

Tom Adamson

Tom Adamson is a writer and editor in the Communication & Outreach Department at the USGS Earth Resources Observation and Science (EROS) Center in Sioux Falls, SD. He develops content for several EROS outreach activities that help explain remote sensing to the general public, including Earthshots, Image of the Week, Earth As Art, and the Tracking Change Over Time lesson plan. He is also one of the tour guides. Before working at EROS, Adamson was an editor at a publishing company that publishes nonfiction children's books for the school library market. He continues to write nonfiction books for children on wide ranging topics: extreme sports, planets, football teams, elementary mathematics, the science and technology of sports, and even tae kwon do. Communicating science effectively to kids and to the general public turns out to be a very similar skill. Adamson lives in Sioux Falls with his wife and two sons.

Aida Awad
Aida Awad has been the Science Department Chair for Maine East High School in Park Ridge, IL since 2003 and an adjunct at Oakton Community College since 2010. She is the current Secretary/Treasurer of NAGT, and NAGT Past President. Her focus is on the implementation of the Next Generation Science Standards and the Framework for K-12 Science Education, specifically focusing on Earth and Space Science, and on teacher professional development in K-12 science education. Aida was a co-convener of the NAGT AGI NGSS Summit in April 2015, and an NGSS Implementation workshop leader at the Earth Educator Rendezvous in July 2015. She continues to be an active member of the InTeGrate Assessment Team.



Daniel Birdsell
Daniel Birdsell is pursuing a PhD at the University of Colorado in Civil Engineering. He studies environmental impacts of oil and gas development in the subsurface such as the migration of hydraulic fracturing fluids and the geo---mechanical impacts of Class II disposal wells. He helped teachers in Colorado develop a curriculum for teaching about ecosystem services focused on oil and gas development. Daniel holds a B.S. in Chemical Engineering from the University of New Mexico.

Dr. Luke Bowman
Luke Bowman has a PhD in Geology from the Geological and Mining Engineering and Sciences Department at Michigan Technological University. Luke also holds a B.A. in Geology from Hanover College and a M.S. in Geology from Michigan Tech. Luke studied geological hazards and disaster risk reduction in El Salvador through U.S. Peace Corps and U.S. Fulbright-funded field investigations. In addition to community-based, citizen science field work in Latin America, Luke also developed K-12 science curriculum as a Fellow with the GK12: Global Watersheds program partnering with schools in the Upper Peninsula of Michigan and Sonora, Mexico. Luke served as a content expert for Mi-STAR unit development and currently develops curriculum and coordinates pilot teachers for the Mi-STAR project.

Edna DeVore

Edna DeVore is the Director of Education and Public Outreach (EPO) at the SETI Institute. She is a science and astronomy educator. Her work with NASA includes Reaching for the Stars: NASA Science for Girl Scouts, NASA's Kepler Mission, Astrobiology Institute research program, NASA's Stratospheric Observatory for Infrared Astronomy (with USRA), and Co-I for NASA & NSF Research Experience for Undergraduates in Astrobiology. She was Co-I for NSF funded "Voyages Through Time: An Integrated High School Science Curriculum on the theme of evolution. DeVore served on the Board of Directors for the Astronomical Society of the Pacific for 6 years. Formerly, she was a member of the Astronomy Education Board of the AAS, the Education Board for the Foundation for Microbiology, and several advisory boards for NASA and NSF EPO projects. Previously, she taught astronomy and directed planetarium programming for grades K-14. Honors include Silicon Valley Women of Influence 2015, Women in Aerospace's Public Awareness Award 2005, NASA ARC Contract Employee Award 1995, US DOE Christa McAullife Teaching Fellow 1987, Outstanding Student Researcher, School of Education, San Jose State University in 1989 and the California State University Student Research Competition, 2nd Place for Education statewide, ASTC Honor Roll of Teachers in 1987, Fellow of the International Planetarium Society. Professional activities include American Astronomical Society, American Geophysical Union, American Association of Physics Teachers, National Science Teachers Association, planetarium and amateur astronomy organizations. She has published more than 30 papers on science, and astronomy education. She's presented over 200 invited talks, teacher workshops and short courses at science education conferences. BA: Raymond College at University of the Pacific, 1964; California teaching credential San Jose State University 1977; MA in Instructional Technology/Education from SJSU 1988; MS in Astronomy at University of Arizona 1992.

Mary Engels

Mary Engels is currently a doctoral student at the University of Idaho where she studies how vegetation changes alters the water balance of small oceanic islands. Her interest in this subject came from spending many years visiting these islands while sailing as a scientist and educator with the Sea Education Association (SEA). During her eight years with SEA she actively collected and analyzed marine debris from large swaths of the Pacific Ocean, Atlantic Ocean, and Caribbean Sea. She continues to be involved in educational initiatives around this important issue, including developing marine debris lessons plans for NOAA as part of a series of lessons about the Pacific Marine National Monuments. She has a MS in Geology and Geophysics from the University of Hawaii, spent two years as a NSF GK12 Fellow, and is currently managing The Confluence Project. This project brings together UI graduate students, K-12 science teachers and students, and community experts to facilitate problem-based, field science investigations around local water resource issues.

Dr. Lisa Gardiner
Lisa Gardiner leads K-12 curriculum development and teacher professional development at the UCAR Center for Science Education. She holds a PhD in Geology from the University of Georgia and an MFA in Nonfiction Writing from Goucher College. She has worked in diverse education settings from universities to nature centers and farms. In her current role, she creates educational experiences for classrooms, blogs, websites, museum exhibits, interactives, and books and instructs teacher PD workshops and online courses.

Emily Gochis
Emily Gochis is a PhD candidate studying hydrology and geoscience education at Michigan Technological University. Additionally she holds a B.S. in Natural Resource Management and a M.A. in Secondary Education from the University of Michigan. Before beginning her PhD she spent several years as a high school science teacher, an outdoor educator, and environmental education specialist. During her PhD studies she also had the opportunity to serve as an NSF GK12 fellow, building and maintaining a close partnership with science teachers from a Native American K12 School in Michigan's Upper Peninsula. She has had the opportunity to work with in-service K12 teachers in several settings over the past decade including single and multiday geoscience field institutes, science education professional development workshops, environmental education workshops and most recently facilitated multi-week NGSS integrated STEM curriculum development workshops for the Mi-STAR program (http://mi-star.mtu.edu).

Alan Gould
Alan Gould has been Co-Investigator for Education and Public Outreach for the NASA Kepler Mission since 2000. Based at The Lawrence Hall of Science, University of California Berkeley, he also directs the Global Systems Science high school curriculum project, Co-Directs the Hands-On Universe project, was Director of the LHS Planetarium for over a decade, is co-author of Great Explorations in Math and Science (GEMS) teacher guides, and is currently on the Full Option Science System (FOSS) middle school course revision team. He has over 40 years of experience developing and presenting hands-on science activities and 25 years of experience organizing and leading teacher education workshops. See http://www.uncleal.net/alan.

Katya Hafich

Katya Hafich splits her time at University of Colorado Boulder between coordinating the education and outreach program at the AirWaterGas Sustainability Research Network, and coordinating K-12 and community outreach programs at the CU Boulder Office for Outreach and Engagement. She's a recovering biogeochemist, and now works with K-12 teachers, community groups, and faculty on global issues of climate change and hydraulic fracturing.

Dr. Robert Handler

Robert Handler is a Senior Research Engineer and Operations Manager of the Sustainable Futures Institute at Michigan Technological University, where he coordinates sustainability-themed research and education activities between several university departments. He earned his PhD in Environmental Engineering from the University of Iowa, and prior to his graduate work he completed a BA in chemistry from Gustavus Adolphus College. His research at Michigan Tech deals primarily with alternative energy systems and environmental life-cycle assessment. He has contributed to the Mi-STAR team through curriculum development, and has worked with several K-12 teacher groups in the past at Michigan Tech through summer teacher training institutes, involving biofuels, life-cycle thinking, and sustainable food systems.

Tori Hellmann

Tori Hellmann is a science teacher at Palisade High School in Palisade, Colorado where she has taught Geophysical Science, Biology, Honors Biology, Zoology, Botany, AP Environmental Science and IB Biology. She is also the advisor for the MESA club, which involves STEM activities and competitions in Colorado. Previously Tori taught middle school science at Holy Family Catholic School in Grand Junction, Colorado. She holds a master's degree in science education from Montana State University and a bachelor's degree in elementary education K-8 from Northern Arizona University. Her interest in science began at Colorado State University where she majored in watershed science. This past summer Tori was a Teacher-in-Residence with the AirWaterGas project, developing science curriculum about the impacts of oil and gas development.

Greg Lackey
Greg Lackey is a PhD candidate at The University of Colorado, Boulder. His primary research interest is the multiphase transport of stray methane away from leaky oil and gas wellbores. Greg is also very interested in environmental education. He spent two years working as a teaching resident assistant for the Sustainability and Social Entrepreneurship Residential Academic programs at the University of Colorado. He has also been a part of the education and outreach team for the AirWaterGas Sustainability Research Network.

Steve Mattox
Steve Mattox is a Professor of Geology at Grand Valley State University where he specializes in training preservice science teachers. He coordinated the GVSU hub for Mi-STAR in the summer 2015, participating in creating the Water Cycle module and leading the effort on the Weather and Climate module. Steve's prior experience includes MTU's MITEP program. Other projects include building a credit-by-exam program for high school students to earn college credit for their geology course at Michigan universities. Steve and his GVSU students commonly present at national and state geology and science teacher meetings. Prior to joining GVSU Steve worked as an exploration geologist in West Australia and Indonesia.

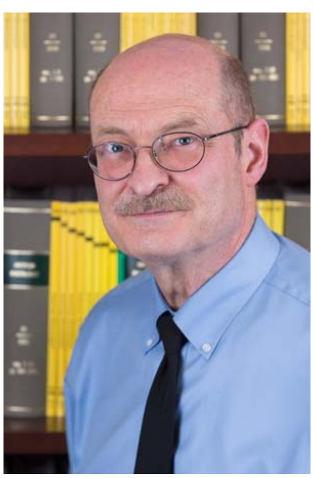
Dr. Carla McAuliffe
Dr. Carla McAuliffe is the Executive Director of the National Earth Science Teachers Association (NESTA), an organization devoted to facilitating and advancing excellence in K-12 Earth and Space education. She currently works for TERC, a nonprofit research and development organization based in Cambridge, Massachusetts, dedicated to STEM (Science, Technology, Engineering, Mathematics) and STEAM (Science, Technology, Engineering, Arts, Mathematics) education. At TERC since 2001, Dr. McAuliffe leads, manages, and works on a number of science education projects including those funded by the National Science Foundation, the U.S. Department of Education, and the National Aeronautics and Space Administration. She develops print and Web-based instructional materials, facilitates professional development experiences, creates evaluation instruments, conducts educational research, disseminates project findings and products at national meetings and conferences, and obtains external funding to support these efforts. Dr. McAuliffe has led many professional development, curriculum development, and research programs focused on Earth science education. She has taught middle school and high school science along with university science education courses for teachers. Dr. McAuliffe holds a Ph.D. in Learning and Instructional Technology with an emphasis in Science Education from Arizona State University.

Laura Nelson

Laura Nelson recently received a master's degree in Marine and Environmental Affairs from the University of Washington. There her research focused on ocean literacy and marine science education and she was part of a NOAA funded educational project. This project involves the creation of a series of lesson plans about the Pacific Marine National Monuments. Her interests in these subjects arose from many years of working on educational tall ships where she taught marine science and oceanography to students ranging from 2nd grade to college undergraduates. While at the Sea Education Association, Laura was a scientist responsible for the collection and analysis of a range of oceanographic data, including marine debris, which fueled the research of both faculty and students onboard the vessel. Laura is currently finishing up the Marc Hershman Marine Policy Fellowship where she has been working with The Nature Conservancy and The Makah Tribe in Washington State.

Doug Oppliger

Doug Oppliger is a licensed professional engineer who holds the rank of Senior Lecturer in the Department of Engineering Fundamentals at Michigan Technological University. In addition to university teaching he has led several K-12 STEM educational initiatives aimed at involving teachers and students in authentic teaching and learning. He facilitated five weeks of teacher professional development during the summer of 2015 for the Mi-STAR project. In addition to his work with Mi-STAR, he has designed and facilitated many K-12 teacher workshops involving underwater remotely operated vehicles, 3D printers, project learning, and the integration of science standards. He has been awarded several grants from the National Science Foundation and other agencies to fund this work at the nexus of STEM, K-12, and higher education. He has presented papers at many national and international conferences on K-12 engineering education. Doug is also a member of the Michigan NGSS review team.



Dr. Alex Speer

J. Alex Speer is the Executive Director of the Mineralogical Society of America (MSA) with past employment as a teacher, researcher, and manager in both industry and acasdemics. He received a B.S. in geology from Franklin and Marshall College (1970) and a M.Sc. (1973) and Ph.D. from Virginia Polytechnic Institute and State University (1976). After graduation, he began his career locating and evaluating potential low-temperature geothermal energy resources and sites for high-level radioactive waste depositories in the southern Appalachians. From 1982-1987 he worked for a manufacturer of precision sliprings: rotary joints for electrical, pneumatic, hydraulic, and optical applications. From 1987-1994 he taught at North Carolina State University, where he also continued work on the geology of the Alleghanian granites of the southern Appalachians and on soil-gas radon. He arrived at MSA at the start of 1995 as Administrator, then Executive Director in 2000. The position comprises three roles: office management, finances, and executive director. The last role is more public and entails the development, evaluation, and execution of all existing and new MSA programs. Developments in this role over the past 20 years include: re-organization of MSA as a society and a corporation, new production technology of scientific publications (journal, books, textbooks, magazine) as well as their delivery and marketing, new office and warehouse space, internet present for both the society and its publications, Mineralogy 4 Kids, short courses, the lecture programs, awards, grants, and relations with other member society organizations.

Dr. Susan Sullivan

Dr. Susan Sullivan is Director of the Education and Outreach Group at the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado Boulder. She has provided professional learning opportunities for educators since 1996. Her work has focused on climate education, digital learning resources and integration of education and geosciences research across Earth Systems Science. As part of her work with the National Association of Geoscience Teachers, Dr. Sullivan is interested in supporting the implementation of the Next Generation Science Standards.

Stephanie Tubman

Stephanie Tubman holds a Master's in Geology from Michigan Technological University, with an emphasis on natural hazards and water resources. During her Master's degree studies she worked with middle school science teachers in the United States and in Guatemala to develop inquiry-based lessons on natural hazards, natural resources, and climate change. Most recently she has facilitated multi-week curriculum development workshops for middle school and high school teachers participating in the Mi-STAR project. These workshops have included professional development activities on geoscience content and the Next Generation Science Standards.

Dr. Naga Manohar Velpuri

My research interests are focused on the overlapping areas of surface hydrology, remote sensing, and climate change. Current research projects broadly cover understanding (a) multi-scale watershed hydrologic processes (b) variability in surface water storage using multi-source satellite data (c) climate and human impacts on water resources availability, and (d) water availability and use analysis across scales.

From ship to shore: Communications from the front lines of marine debris research - Mary Engels (University of Idaho) and Laura Nelson (Sea Education Association)

NOAA FISHERIES

Papahānaumokuākea Marine National Monument: Marine Debris

Grade Level

- 7-12

Timeframe

- Three 45-minute periods, two 90-minute periods

Key Words

- Nautical Mile
- Marine Debris
- Remote Sensing
- Duplicate Sampling
- Gyre
- Biofouling
- Weathering

Activity Summary

This lesson serves as an introduction to Papahānaumokuākea Marine National Monument (PMNM) and to one of the most difficult management challenges facing the Marine National Monument system, *Marine Debris*. The enormous size of PMNM, its remoteness, and the limited resources available for cleanup make addressing the issue of marine debris in the Monument a difficult one to manage. In this lesson students will explore the distribution, types and impacts of marine debris found in PMNM. That will be followed by an investigation on what types of plastic are likely to end up as marine debris and the possible sources of marine debris to PMNM.

Learning Objectives

Students will be able to:

1. Describe the size and location of PMNM
2. Describe the different scales of marine debris
3. Understand different sizes and types of marine debris.
4. Understand the impacts of marine debris
5. Use replicate testing to determine physical properties of plastic
6. Understand the life cycle of marine debris

Vocabulary

BIOFOULING – the accumulation of microorganisms, plants, or algae on a wetted surface.

GYRE – a large oceanic region of slowly circulating currents, driven by global winds and the Coriolis Effect.

MARINE DEBRIS – NOAA defines as any persistent solid material that is manufactured or processed and is directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes.

NAUTICAL MILE – a unit of measure commonly used in marine navigation that represents one minute of arc along any meridian of the earth and by international agreement has been set at 1,852 m.

REMOTE SENSING- is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites. Remote sensors collect data by detecting the energy that is reflected from Earth.

REPLICATE SAMPLE – a second (or third, fourth, etc…) sample of the same material collected under the same conditions which is usually used to estimate sample variability.

WEATHERING – the breakdown of material due to prolonged exposure to various environmental conditions (water, salt, sun, ice, wind, wave action, etc).

Background Information

Marine Debris:

The remote location and historically low levels of human visitation have left PMNM in relatively ecologically pristine condition with one major exception, ***marine debris***. NOAA and the USCG define marine debris as any persistent solid material that is manufactured or processed and directly or indirectly, intentionally or unintentionally, disposed of or abandoned into the marine environment or the Great Lakes (33 USC 1951 et seq. as amended by Title VI of Public Law 112-213) (Lippiatt et al, 2013). Huge amounts of consumer plastics, metals, rubber, paper, textiles, derelict fishing gear, vessels, and other lost or discarded items enter the marine environment every day, making marine debris one of the most widespread pollution problems facing the world's ocean and waterways.

This lesson plan focuses on possible sources of marine debris to PMNM, the types of marine debris found on the beaches of Papahānaumokuākea, how density differences among plastics make some more likely to end up as marine debris, and possible impacts of debris to the marine environment in Papahānaumokuākea. Below is some additional background on the sources, types, impacts, and dispersion of marine debris.

Sources of Marine Debris:

Ocean-based Sources

Materials can fall, be dumped, swept, or blown off vessels and stationary platforms at sea. Ocean-based sources of marine debris include:

- **Fishing Vessels** – Fishing gear may be lost from commercial fishing vessels as well as from recreational boats and from shore-based fishing activities.
- **Stationary Platforms** – Offshore oil and gas platforms are surrounded by water, and all items lost from these structures become marine debris. Marine debris generated from these platforms includes plastic drill pipe thread protectors, hard hats, gloves, and 55-gallon storage drums, among others.
- **Cargo Ships and Other Vessels** – Cargo lost overboard from freighters, cruise ships and other vessels poses serious threats to marine navigation. Container vessels caught in rough seas can lose the contents of their containers (plastic resin pellets, sneakers, televisions, plastic toys, etc.), or perhaps even the entire container, a steel box 6 – 12 meters long, 2.4 meters wide and 2.9 meters high. Vessels carrying logs or lumber may lose large bundles or individual pieces of wood.

Land-based Sources

Materials

- Student handout
- Computers with internet access and Google Earth/Atlas
- Six clear beakers or small see through containers per group (9 oz small clear plastic cups work well)
- Paper towels
- Tweezers, enough for one pair per group of two to three students.
- Disks of six different types of plastic (recycle codes 1-6) made with a hole punch. Enough for three each per group.
- Lab glasses and gloves enough for each student.
- Handout for teacher explaining different types of plastic and their recycling codes and density characteristics.
- Six premixed density solutions, enough for 50 ml each per group (see solution mixing chart below)

Outline

ENGAGE – Introduction to Papahānaumokuākea Marine National Monument

EXPLORE – Model dispersion of marine debris, determine types and sizes of marine debris.

EXPLAIN – Discussion of type, sizes, and impacts of marine debris

ELABORATE – Investigation of plastic density and how that impacts dispersion potential

EVALUATE – Life cycle of marine debris in PMNM

Debris generated on land can be blown, swept, or washed out to sea. Littering, dumping in rivers and streams, and industrial losses such as spillage of plastic resin pellets during production, transportation, and processing are typical sources for land-based debris.

- **Littering, Dumping, and Poor Waste Management Practices** – Intentional or unintentional disposal of domestic or industrial wastes on land or in rivers and streams can contribute to the marine debris problem if a subsequent action carries the debris to the ocean.
- **Stormwater Discharges** – Stormwater that flows along streets or along the ground as a result of rain or snow can carry street litter into storm drains. Storm drains carry this water and debris to a nearby rivers, streams, canals, or even directly to the ocean. Marine debris from stormwater runoff includes street litter (e.g., cigarette butts and filters, motor oil, tire fragments), medical items (e.g., syringes), food packaging, beverage containers, and other material that might have washed down a storm drain.
- **Extreme Natural Events** – Hurricanes, tornadoes, tsunamis, floods and mudslides have devastating effects on human life and property. The high winds, heavy rains, flooding, and tidal surges associated with extreme events are capable of carrying objects as light as a cigarette butt or as heavy as the roof of a two-story home far out to sea. During storms or other periods of strong winds or high waves, almost any kind of trash (including glass, metal, wood, and medical waste) can be deposited into the ocean.

Types of Marine Debris:

Plastic is one of the dominant materials found in collections of marine debris around the world, though anything man-made, including litter and fishing gear, can become marine debris once lost or thrown into the marine environment. The most common materials that make up marine debris are plastics, glass, metal, paper, cloth, rubber, and wood.

Derelict fishing gear refers to nets, lines, crab/shrimp pots, and other recreational or commercial fishing equipment that has been lost, abandoned, or discarded in the marine environment. Modern gear is generally made of synthetic materials and metal, so lost gear can persist for a very long time.

Glass, metal, and rubber are used for a wide range of products. While they can be worn away and broken down into smaller and smaller fragments, they generally do not biodegrade entirely. As these materials are used commonly in our society, their occurrence as marine debris is overwhelming.

Plastic has been designed to be durable, lightweight, and strong. In addition, many plastics have densities close to or less than the density of water (See *Overview of Plastic Types* included with lesson materials). In combination this means that plastics do not break down quickly in the marine environment and that they are able to disperse over long distances by floating at or near the surface of the water.

Impacts of Marine Debris:

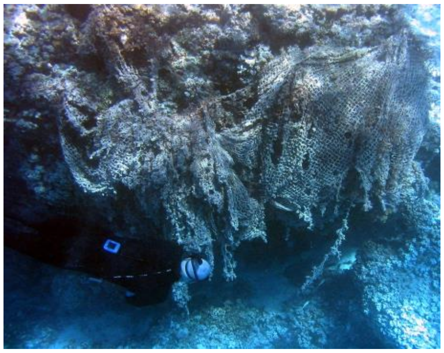
Below are just a few of the ways in which marine debris becomes a significant problem in the marine environment.

Ingestion:
Many animals, such as sea turtles, seabirds, and marine mammals have been known to ingest marine debris. The debris item may be mistaken for food and ingested, an animal's natural food (e.g. fish eggs) may be attached to the debris, or the debris item may have been ingested accidentally with other food. Debris ingestion may lead to loss of nutrition, internal injury, intestinal blockage, starvation, and even death.

Wildlife Entanglement and Ghostfishing:
One of the most notable impacts from marine debris is wildlife entanglement. Derelict nets, ropes, line, or other fishing gear, packing bands, rubber bands, balloon string, six-pack rings, and a variety of marine debris can wrap around marine life. Entanglement can lead to injury, illness, suffocation, starvation, and even death.

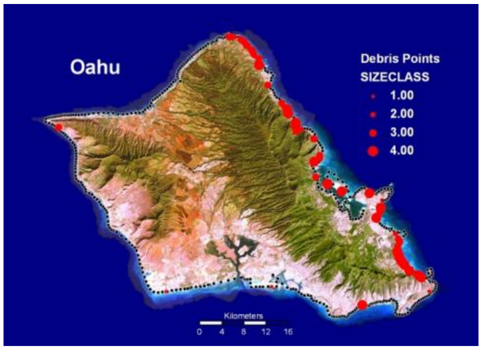

Alien Species Transport:
If a marine organism attaches to debris, it can travel hundreds of miles and land on a shoreline where it is non-native. In addition, un-attached species may use floating debris as shelter and make long distance ocean crossings. These non-native, potentially invasive species can have devastating impacts on fisheries and local ecosystems by out competing native species, and they may be costly to eradicate once established.


Vessel Damage and Navigation Hazards:
Marine debris can be quite large and difficult to see in the ocean, if it's floating at or below the water surface. Vessel encounters with marine debris at sea can result in costly damage, either to the vessel structure or through a tangled propeller or clogged intake.




Habitat Damage:
Marine debris can scour, break, smother, and otherwise damage important marine habitat, such as coral reefs. Beaches, which are essential nesting sites for seabirds, shorebirds, and turtles, are also

impacted by debris that washes up on shore. Many of these habitats serve as the foundation of important marine ecosystems and are critical to the survival of numerous other species.



Economic loss:
Marine debris is an eyesore along shorelines around the world. It degrades the beauty of the coastal environment and, in many cases, may cause economic loss if an area is a popular tourist destination. Would you want to swim at a beach littered in trash? Coastal communities may not have the resources to continually clean up debris.

Dispersion of Marine Debris:
The impacts of marine debris are felt far beyond the point where the debris enters the water. Differing physical characteristics of marine debris will determine how that debris is dispersed. Some marine debris remains localized close to the point it enters the water, but other buoyant debris can be transported long distances and will impact locations far from it source. PMNM is located in the **North Pacific Gyre** (Figure 1), a large area of the ocean bounded by circulating currents. Much of the marine debris found in PMNM is swept into the Monument by these swirling currents from sources far outside the Monument boarders.

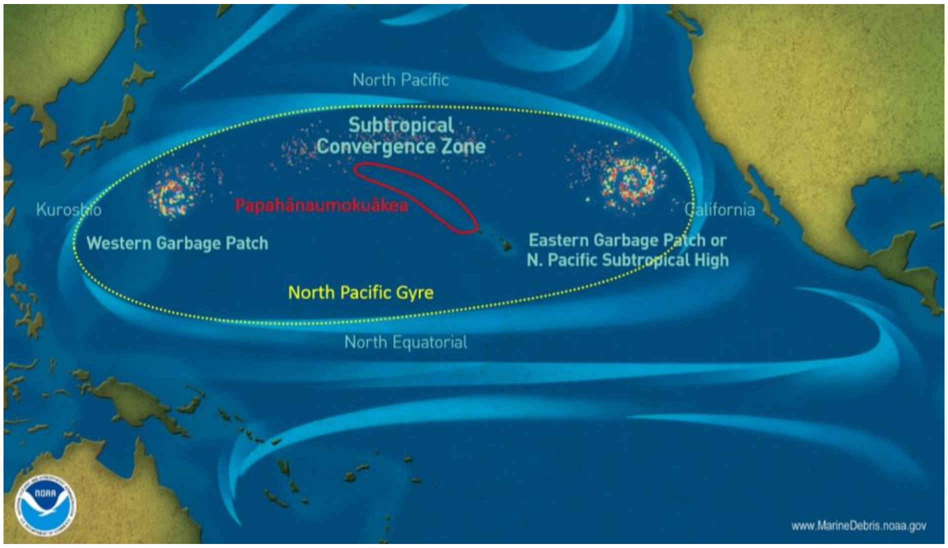


Figure 1. North Pacific Gyre

Preparation

Computer Programs

- If you will be doing the computer portions of this lesson plan, be sure there are sufficient computers with internet access and Google Earth/Map access for each student or group of students.
- Be familiar enough with Google Earth/Maps to be able to assist students.
- Ensure that you are able to access www.adrift.org.au from school computers.

Chemical mixing for plastic density sample testing

- Materials needed: tap water, isopropyl alcohol, and table salt.
- 70% and 91% isopropyl alcohol are the most commonly available formulations at most pharmacies or grocery stores.
- The tables below give amounts of salt and isopropyl alcohol needed to mix solutions for one group of students.

Table 1 (91% isopropyl alcohol)

Solution	ml of H_2O	ml of isopropyl alcohol (91%)	Grams of Salt	Density (g/mL)
A	50	0	17.5	1.35
B	50	0	5	1.1
C	50	0	0	1
D	37	13	0	0.945
E	30	20	0	0.915
F	21	29	0	0.876

Table 2 (70% isopropyl alcohol)

Solution	ml of H_2O	ml of isopropyl alcohol (70%)	Grams of Salt	Density (g/mL)
A	50	0	17.5	1.35
B	50	0	5	1.1
C	50	0	0	1
D	31	19	0	0.945
E	20	30	0	0.915
F	6	44	0	0.876

- When mixing the salt solutions, be sure that the salt completely dissolves.
- Should you care to change the density solutions to some other range of densities, the volume of alcohol needed for each density was determined from the following equations:

$$Vol_{alcohol} = \frac{(\rho_{total} * Vol_{total}) - (\rho_{water} * Vol_{total})}{\rho_{alcohol} - \rho_{water}}$$

The volume of water needed was calculated from:

$$Vol_{water} = Vol_{total} - Vol_{alcohol}$$

The density of the final solution will be:

$$\rho_{solution} = \frac{(Vol_{alcohol} * \rho_{alcohol}) + (Vol_{water} * \rho_{water})}{Vol_{total}}$$

For all these equations we assume these densities:

$$\rho_{water} = 1 \frac{g}{ml}$$
$$\rho_{alcohol\,(70\%)} = 0.858 \frac{g}{ml}$$
$$\rho_{alcohol\,(91\%)} = 0.786 \frac{g}{ml}$$

- The amount of salt needed to get salt solutions of known density is determined by:

$$\rho_{solution} = \frac{(Mass_{water} + Mass_{salt})}{Vol_{total}}$$

Learning Procedure

Engage: Part 1 – Size of a Monument

For this activity the students will need access to an atlas or computers with internet and mapping programs.

Read Part 1 of the Marine Debris Student Worksheet as a class.

Have the students work in pairs to calculate the size of Papahānaumokuākea and to find a land-based comparable distance.

Next ask groups of students to share what locations they discovered and the number or state/countries that this area covers. Follow this up with a discussion on the issues related to managing a region the size of Papahānaumokuākea.

Explore: Part 2 – Marine debris on the move

For classrooms that have access to computer and internet resources have students do the following modelling activity for themselves. For classrooms not equipped with student computer resources, the following activity can be done with projected simulations or by using the model results included in the accompanying PowerPoint. Note that the static image does not show the changing distribution of marine debris with time and so may not highlight possible source countries as well as the dynamic model run.

Have the students navigate to www.adrift.org.au and locate where Papahānaumokuākea would be on the map. Have students run simulations of the distribution patterns of plastic marine debris by clicking on any ocean area. Note, the simulations can be run both forward in time and backward in time (click on button "showing where plastics end up" to change). Both simulation methods should allow students to answer the subsequent questions on the worksheet.

The last question in this section of the student worksheet is an opportunity to reconnect students with how their own actions might contribute to the issue of marine debris. See the *Extending The Lesson* section at the end of this document for some additional ideas about how to engage students to local pollution issues.

Explore: Part 3 – Beach walk

For classrooms that have access to computer and internet resources have students do the following beach walk activity for themselves. For classrooms not equipped with student computer resources, the activity can be done using individual photographs from the accompanying PowerPoint.

The following page has links to each individual island in Papahānaumokuākea that has Google Street View imagery: (http://www.papahanaumokuakea.gov/news/google_streetview.html). Follow these links to look at the beaches of the Papahānaumokuākea in Google Street View and ask the students to explore and to see if they find any visible marine debris.

After some exploration time ask the students to focus on these locations on Lisianski (Papaāpoho) Island (26.056477, -173.961058), and Laysan Island (25.781036, -171.727775). In order to access these locations they should be able type the latitude/longitude coordinates into the Google Maps/Earth search bar and then zoom in until in Street View.

Once in Street View give them 10 minutes or so to identify as many pieces of marine debris as they can (there are milk crates, buoys, laundry baskets, bottles tires, etc) and to record these on their datasheets. They may need to move around while in Street View in order to identify different types of marine debris.

Once the students have a list of marine debris items, ask them to sort those according to the size classes listed in their worksheet and to indicate what materials they think each item is made of. Finally, when they are done recording data, have them answer the associated questions in their worksheet.

Explain: Part 4 – Characteristics of marine debris

After a few minutes to compare data from Part 3 between groups, have the students answer the questions about characteristics of marine debris. Discuss these answers as a class.

To help the students understand the scale of the problem in Papahānaumokuākea, you may want to show this short video about marine debris http://www.youtube.com/watch?v=wJo-DAcXtzo.

More information on marine debris clean ups in Papahānaumokuākea can be found at:
https://pifscblog.wordpress.com/2013/05/29/final-marine-debris-midway/

Elaborate: Part 5 – Float test

As the students investigated above, marine debris is a very significant problem in Papahānaumokuākea, and most other ocean environments and inland water ways. Some of the most persistent types of marine debris are made of pre- and post-consumer plastics. However, not all plastic that enters the marine environment will be dispersed over long distances. Which plastics persist in the marine environment depends on many things, including the type of plastic, what form the plastics take (are they pellet shaped, bottle shaped, etc.), how weathered the plastic is, and so on. The goal of this elaboration section is to investigate how plastic density affects plastics' ability to disperse in the marine environment.

Procedure:

1. Break students into groups. Groups of two to three are ideal.
2. Each group of students should have:
    a. 6 x 50 ml clear containers containing density solutions A thru F
    b. Tweezers
    c. Paper towels
    d. Gloves and goggles
    e. One worksheet per student.
3. Begin by stressing to all the students proper use of gloves and goggles for these investigations.
4. Give each student group two different types of plastic disks (so not all the groups have the same plastics to test).
5. Demonstrate how to test plastic disk in different density solutions. Plastic disks should be clean and dry. Use tweezers to hold plastic disks and avoid touching the disks with your fingers. Oils from your hands can change the apparent properties of the plastic. Using the tweezers place the disk into the density solutions close to the bottom of the container. Shake *gently* to dislodge any air bubbles. Release disk and wait until it stops

moving. Record the behavior of the plastic disk. Does it float, sink or is it neutrally buoyant?

6. Be very careful to stress that they should NOT mix the solutions and that they are careful to clean and dry the pieces of plastic between testing in each solution.
7. Ask the students to test their plastic disks in the different solutions and to record their data on their worksheets. They should do three replicates of each type of plastic.
8. Have each group contribute to a group graph on the board. By the time all groups are finished, all the different plastic types (recycle codes) should be represented on the board.

Give students time either in class or as homework to complete the elaboration questions.

Evaluate: Part 6 – Marine debris life cycle

Have the students create a life-cycle model for a piece of marine-debris that they found in Papahānaumokuākea. This could be either a written or creative assignment depending on needs, time and resources. Questions that the students should address with their life cycle model include: Where did the object enter the environment? How was the object transported to Papahānaumokuākea? What processes impacted the object during its travels? What are potential impacts of that marine debris to the environment? How was the object removed from the marine environment? What is the likely fate of this marine debris? What potential impact could this marine debris have on me? What potential impact can I have on marine debris?

Closing

This may seem like an overwhelming problem, but there are things you can do in your local community to help. Talk to your students about the concepts of reduce, reuse, and recycle. It is much easier to prevent plastic from going in the ocean in the first place than to clean it up later.

Extending the Lesson

- Participate in a beach or park clean-up near your community
- Reuse is a particularly important method of limiting our trash generation. One way to empower students to take action might be to have them keep a log for a week of the things that can be reused that they ordinarily throw away. This is a great discussion and brainstorming tool, as well as an opportunity for peer support around forming low-impact habits.
- Plastic is not the only pollution that ends up in the ocean, have a conversation with your students about chemical run-off, increased CO_2, and other materials that also end up in the ocean.
- Check out some of the other education materials from NOAA's marine debris program. http://marinedebris.noaa.gov/educational-materials

Connections to Other Subjects

- Chemistry
- Ecology
- Biology
- Technology

Related Links

Adrift
NOAA Marine Debris Program
NOAA Marine National Monument Program
NOAA Fisheries Pacific Islands Regional Office
Papahānaumokuākea Marine National Monument

For More Information

NOAA Fisheries Pacific Islands Regional Office
NOAA Marine National Monument Program
1845 Wasp Blvd., Building 176
Honolulu, HI 96818
(808) 725-5000, (808) 725-5215 (fax) pirohonolulu@noaa.gov

Acknowledgement

This lesson is one in a series exploring the geology, biology, oceanography, and ecology of the Pacific Marine National Monuments. It was developed for the NOAA Fisheries Pacific Islands Regional Office.

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Sources

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Morét-Ferguson, Skye, Kara Lavender Law, Giora Proskurowski, Ellen K. Murphy, Emily E. Peacock, and Christopher M. Reddy. "The size, mass, and composition of plastic debris in the western North Atlantic Ocean." *Marine Pollution Bulletin* 60, no. 10 (2010): 1873-1878.

van Sebille, E. (2014), Adrift.org.au — A free, quick and easy tool to quantitatively study planktonic surface drift in the global ocean, J Exp Mar Biol Ecol, 461, 317–322, doi:10.1016/j.jembe.2014.09.002.

Education Standards

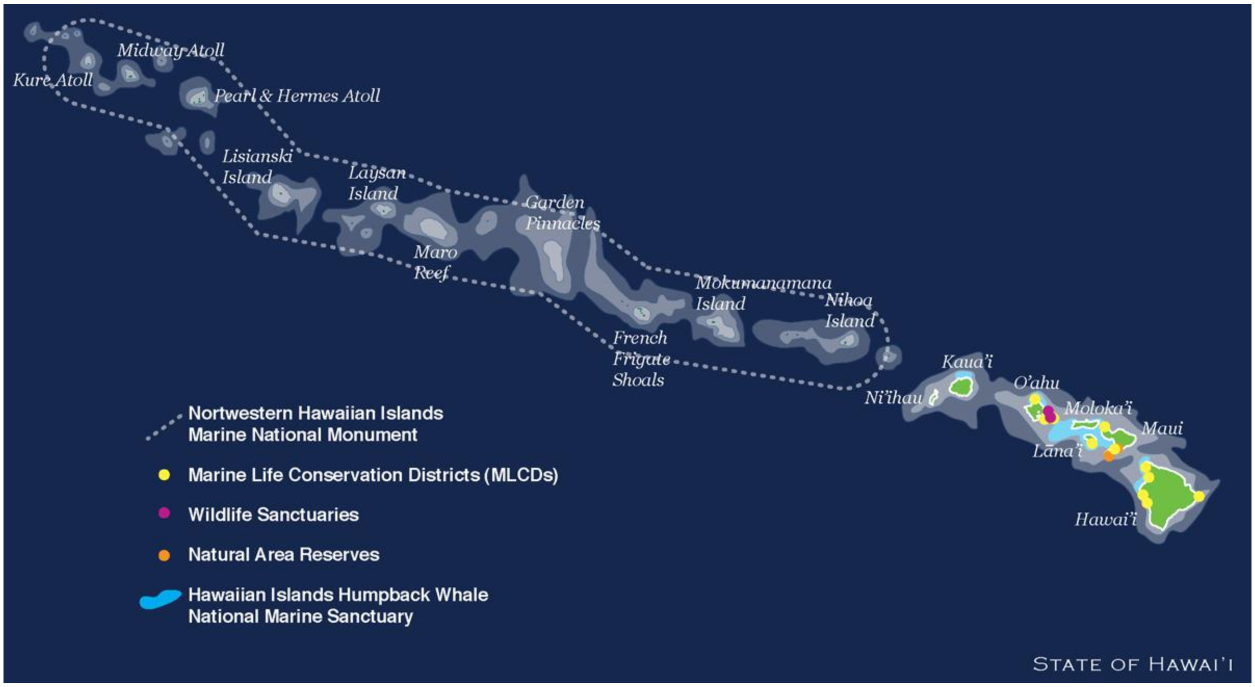
Next Generation Science Standards	• **MS-ESS3-3.** – Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.* [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).] • **MS-LS2-4.** – Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, and on evaluating empirical evidence supporting arguments about changes to ecosystems.] • **HS-ESS3-4**– Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.* [Clarification Statement: Examples of data on the impacts of human activities could include the quantities and types of pollutants released, changes to biomass and species diversity, or areal changes in land surface use (such as for urban development, agriculture and livestock, or surface mining). Examples for limiting future impacts could range from local efforts (such as reducing, reusing, and recycling resources) to large-scale geoengineering design solutions (such as altering global temperatures by making large changes to the atmosphere or ocean).]
Ocean Literacy Principles	• **1A** – The ocean is the defining physical feature on our planet Earth—covering approximately 70% of the planet's surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian, Southern, and Arctic. • **1C** – Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of Earth's rotation (Coriolis effect), the Sun and water density differences. The shape of ocean basins and adjacent land masses influence the path of circulation. This "global ocean conveyor belt" moves water throughout all of the ocean basins, transporting energy (heat), matter, and organisms around the ocean. Changes in ocean circulation have a large impact on the climate and cause changes in ecosystems. • **1E** – Most of Earth's water (97%) is in the ocean. Seawater has unique properties. It is salty, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic. Balance of pH is vital for the health of marine ecosystems, and important in controlling the rate at which the ocean will absorb and buffer changes in atmospheric carbon dioxide. • **1G** – The ocean is connected to major lakes, watersheds, and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments, and pollutants from watersheds to coastal estuaries and to the ocean. • **6D** - Humans affect the ocean in a variety of ways. Laws, regulations, and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (point source, nonpoint source, and noise pollution), changes to ocean chemistry (ocean acidification), and physical modifications (changes to beaches, shores, and rivers). In addition, humans have removed most of the large vertebrates from the ocean. • **6G** - Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Papahānaumokuākea Marine National Monument: Marine Debris Student Worksheet ANSWER KEY

Name_____________________________________ Date____

Part 1: Size of a Monument

Papahānaumokuākea Marine National Monument (PMNM) is the largest conservation area within the United States. It was established in 2006 and in addition to its National Monument status has also been declared a natural and cultural World Heritage Site by UNESCO. PMNM encompasses 139,797 square miles and extends northwest for 1,200 *nautical miles* starting north of the islands of Ni'ihou and Kaua'i, Hawai'i.



Something of this size is hard to for most people to visualize, especially when it consists mostly of water. In order to better understand the size of this conservation area, compare the length of PMNM to a land-based distance that might be more familiar to you. For this you will need an atlas or access to an online mapping program (such as Google Earth/Maps) that will calculate distance.

1. Convert the length of PMNM (1200 nautical miles) to statute miles. Be sure to show your work! Hint: 1 nautical mile = 1.852 km.

   PMNM is ~2,222 km in length (1200 nautical miles x 1.852 km/1 nautical miles).

2. Using an atlas or Google Earth/Maps, find a distance between two points that is comparable to the length of PMNM. What are those two points?

PMNM covers about the same distance in length as the distance from Vancouver, BC and San Diego, CA, USA. Huge!!

3. How many states and or countries does your land-based calculated distance cross?

The goal is to get students to really grasp the enormous size of Papahānaumokuākea. In the above example this distance covers parts of two countries and three states. PMNM is the size of the entire west coast of the US.

4. What might be some issues with trying to manage an area the size of PMNM?

Answers will vary but reasonable thoughts might include issues of managing access, doing any kind of effective policing, rescue operations, know who and what is actually in PMNM, etc…..

Part 2: Marine debris on the move

Surprisingly, one of the significant issues in PMNM is trash. This is particularly striking since there are no permanent human residents in PMNM. Almost all the trash found in Papahānaumokuākea is generated outside PMNM and introduced into PMNM by visitors, fishing boats and ocean currents in the form of ***marine debris***. Whether through ocean dumping, loss of fishing gear, or litter being washed out to sea in rivers, all the countries in and around the Pacific Ocean are possible sources of marine debris. In order to determine how marine debris moves around in the ocean scientists create models of ocean surface currents and track how debris particles move over long periods of time. Today we will make use of one of these models to investigate where marine debris in Papahānaumokuākea may have originated.

Directions: Using a computer with internet access, navigate to www.adrift.org.au and locate Papahānaumokuākea (note you can click and drag the map to reposition). Next, spend some time exploring possible sources of marine debris to PMNM.

1. List five countries in the Pacific region that are modeled to be sources of marine debris to PMNM.

   US, Canada, Mexico, all Central American countries, Japan, Korea, China, most of southeast Asia

2. List three countries in the Pacific region that are **not** modeled to be sources of marine debris to PMNM.

   Chile, New Zealand, Tasmania, Peru, and most of Australia

3. What are other likely sources of marine debris to PMNM besides the countries you listed above?

Debris from ships at sea (cruise ships, tankers, navy, etc) and derelict fishing gear are also big sources of marine debris.

4. What are some ways we can prevent marine debris from impacting PMNM and waters closer to home?

The primary way to keep marine debris from impacting Papahānaumokuākea and waters closer to home is to prevent debris from entering water ways in the first place. Since much of the marine debris comes directly from our waste stream, keeping trash out of the waste stream altogether is important (reduce, reuse, recycle). In addition, anything that keeps trash from accessing the water is beneficial. Proper disposal of trash at home, school, beaches, parks and playgrounds is essential. Supporting dedicated public trash and recycling bins, keeping trash out of open spaces such as streets, sidewalks, parking lots and storm drains, and participating in and organizing cleanups will all help reduce the amount of marine debris. In addition, supporting legislation that changes the way we handle waste on a local, state and national level will help stem the marine debris problem.

Part 3: Beach Walk

Now that you have determined where some of the marine debris might be coming from, it will be important to determine what types of marine debris are actually ending up in PMNM. Unfortunately getting to the islands to survey marine debris is both time consuming and expensive. When faced with situations similar to this, scientists will often turn to ***remote sensing*** techniques to gather data. These techniques allow data to be collected about an object or an environment without the scientist being physically present. Probably the oldest and most well-known form of remote sensing is photography, but other techniques include sonar imaging (radar), multispectral imaging, infrared sensing, and satellite observations, to name just a few. Today we will make use of a series of photographs taken in PMNM to try and determine what types of marine debris actually end up in PMNM.

Directions: Find as many different pieces of marine debris on Lisianski Island (26.056477, -173.961058) or Laysan Island (25.781036, -171.727775) you can and list them below. As you list the pieces of marine debris, classify them by size (see chart on the next page), type of material, and likely source of the debris. Use the data you collect to help answer the questions on the following pages.

Marine Debris Item Type	Item Count	Size Class	Material	Source
Fishing Floats	**#**	**Macro**	**Plastic, rubber, etc.**	**Fishing Vessel**
Totals		**-NA-**	**-NA-**	**-NA-**

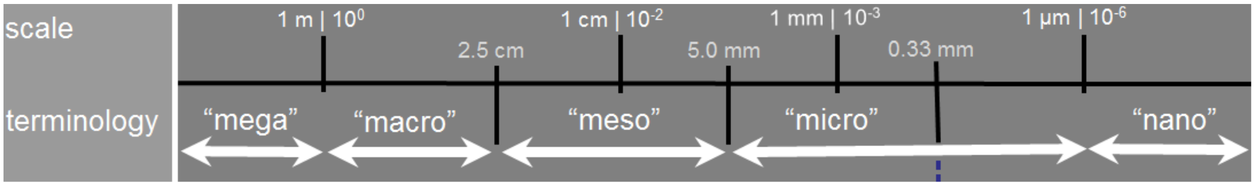


Figure 1: Size classes of marine debris from Lippiatt, S., Opfer, S., and Arthur, C. 2013.

1. What is the dominant size class of marine debris that you found? What percentage of your items fall into this size class?

   Most likely the pieces of marine debris they ID will be in the macro or mega categories. Percentages will vary by student.

2. What was the most common material you found in your marine debris survey?

   Plastic materials are likely to be the most common type of marine debris, followed closely by rubber and glass.

3. What do you think is the most common source of marine debris in PMNM?

   Answers will vary as to what they think is the most likely source of the marine debris, but the number of fishing floats suggests that ships are a likely source of marine debris to PMNM.

Part 4: Characteristics of marine debris

Compare your data with another group of students. As a group discuss and answer the following questions.

1. What characteristics make a material very likely to become marine debris? Does the most common material in your survey have all of these properties?

   Material very likely to become marine debris are typically strong, able to float, resistant to degradation by the sun, and of a size that is easily transportable by the body of water they enter (ie plastic bottles are easier to move downstream then abandoned cars).

2. What sizes of marine debris did you NOT find in your visual survey? Where do you think this size of marine debris might be in the environment? How might you go about counting this size of marine debris?

   The size of marine debris that is unlikely to be found in this visual survey is anything in the "micro" or "nano" category. This debris is present in the environment and mixes well with the sand. It is also very prevalent in the oceans where larger scale marine debris is rarer. This video is useful for understanding where and how this small scale marine debris collects in the ocean.
   http://www.youtube.com/watch?feature=player_embedded&v=IZ27jWzbIU0.

3. List some major impacts (both positive and negative) of marine debris in the environment.

   Hazards associated with marine debris certainly outweigh the benefits. Some of the well-known concerns include entanglement, ingestion, chemical leaching, smothering reefs, and general environmental blight. Interestingly, for some species there may be some benefits including transportation, breeding habitat, new food sources (bacterial) and protection. This is an excellent time to foster discussion about the human impact on ocean ecosystems.

Part 5: Float test

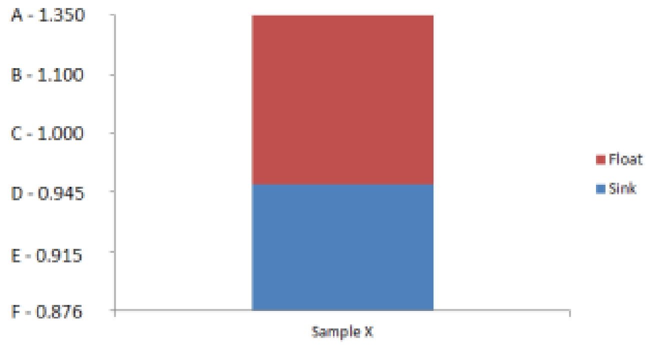
Experimental Data Collection: In your group, use tweezers to test if the plastic pieces float or sink in each of the solutions. You should test each piece of plastic in each solution. Make sure there were no anomalies in your test by testing a second piece of the same type of plastic. This type of testing is called **replicate sampling** and is commonly used by scientists to help ensure accuracy of their sampling data. Make sure you label each sample in the boxes below. You have three pieces of each type of plastic. Make sure you test each separate piece. When you are done use your data to begin making a graph on the following page (**be sure to read the directions!!**).

	Solution A Density: 1.35	**Solution B Density: 1.10**	**Solution C Density: 1.00**	**Solution D Density: 0.945**	**Solution E Density: 0.915**	**Solution F Density: 0.876**
Sample X Replicate 1 (example)	**Floats**	**Float, barely**	**Sinks**	**Sinks**	**Sinks**	**Sinks**

Sample ___ Replicate 1						
Sample ___ Replicate 2						
Sample ___ Replicate 3						

Sample ___ Replicate 1						
Sample ___ Replicate 2						
Sample ___ Replicate 3						

Experimental Data Visualization: Working with your group, use the space provided below to graph your results. Be sure to leave enough room to include data from the rest of the groups in the class (hint: each group will have three observations to graph). Once everyone is done graphing their personal data we will compile data from all groups on the board. Please use a stacked bar type graph that shows the relationship between the density of the solution and where plastic samples floated and sank (see example). Make sure that you label your axes and use the **average** of your observations.



Experimental Data Explanation: Use your data and the class data to answer the following questions. Work with your partner to complete the worksheet.

1. What property of the plastic do you think is responsible for which pieces float and which ones sink?

   The goal with this question is to get the student to describe how some plastics are denser than others. They will probably describe this in terms of floating and sinking.

2. If the plastic pieces you tested were 100 times bigger, would your results be different? Why or why not?

   This question is to re-enforce the concept that density is an intrinsic property, meaning it will be the same regardless of size of the piece of plastic. However, the shape that plastic takes may alter the apparent density. For example, a plastic water bottle which is made of PETE (polyethelyene tetraphalate) has a density of 1.38-1.39 g/ml, which means it should sink in both fresh (1.00 g/ml) and salt water (1.025 g/ml) and yet because the closed bottle traps air it will float for long distances on the open ocean. When weathering finally breaks the plastic down and allows water inside the bottle the density of the plastic alone will now control the buoyancy and at this point it will sink out of the surface water.

3. Based on your tests, what are the density ranges of your samples? Based on that density range, what type of plastic (by recycle code) is your unknown plastic?

   Answers will vary depending on the samples. However, the main concept the students should understand that they are not able to determine an exact density for their plastic sample, only that their plastic falls within a range of densities.

4. If you were told that solution C was fresh water, given what you know from your tests, which plastics (by recycling codes) are most likely to end up in the marine environment? Why do you think that?

   The goal here is to have the students use their collected data (from the whole group) to understand that any plastic that floats in fresh water is likely to end up in the ocean, but the plastics that sink in fresh water will not get there as easily. Analysis of surface plastic from the Atlantic Ocean indicates that the vast majority of plastic that ends up in sea surface collections are made of polypropylene and polyethylene, both which are less dense than freshwater. By contrast, almost no polyethylene terephthalate (PETE) was found in surface collections, though PETE forms a significant portion of plastic debris on beaches (Morét-Ferguson et al., 2010).

5. What physical property of the plastic could change naturally in the marine environment that might cause plastic pieces to sink out of the surface water?

   This question is trying to drive home the idea that density of the plastic relative to the seawater is controlling if the plastics float or not. Changes to the density, therefore, will determine if the pieces remain floating or if they will eventually settle out of surface waters. Removal from surface waters does not eliminate the impacts of these plastic and they will continue to alter benthic marine habitats and food webs while on the seafloor.

6. What do you think might naturally cause such a change?

   ***Biofouling**, which is the accumulation of micro-organisms, plants, algae and animals on a wet surface, is very common on marine debris and will increase the density of the whole object (plastic + biological organisms). **Weathering** breaks down plastics into smaller pieces which more easily have their density altered by biofouling. Weathering may also eventually rupture sealed containers that float as a consequence of displacement, at which point they will sink if the density of plastic is greater than that of the surrounding water.*

Part 6: Marine debris life cycle

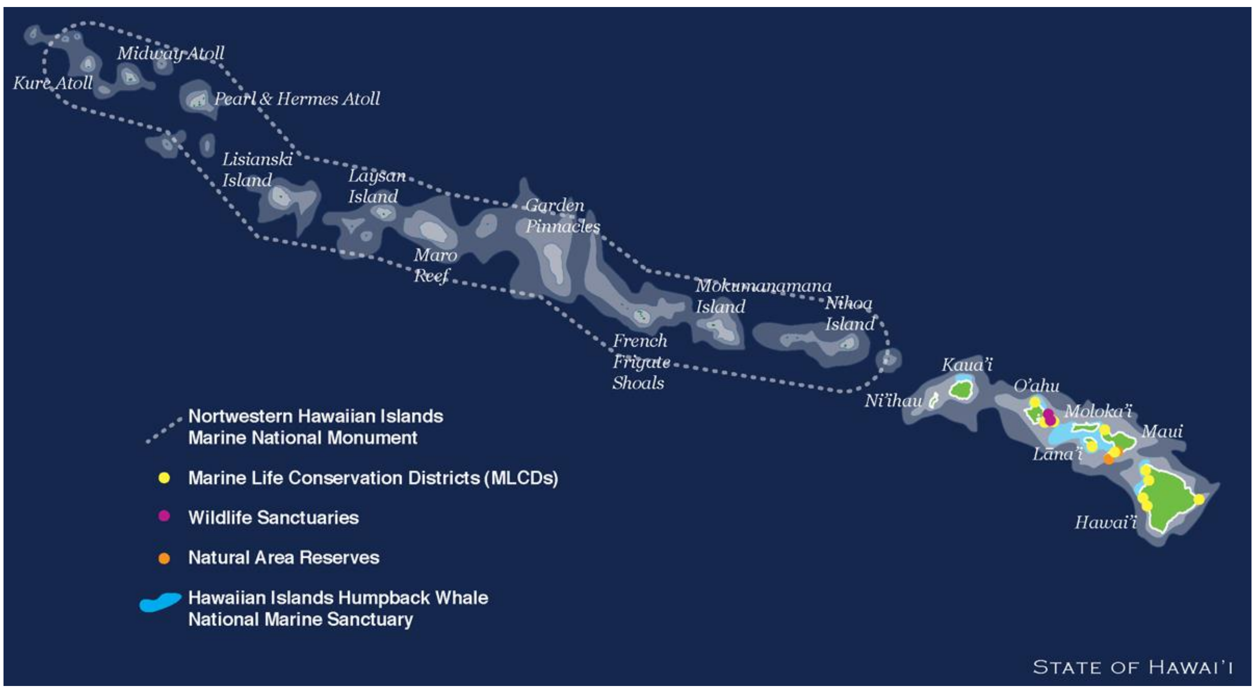
Create a life-cycle model for a piece of marine-debris that you found in Papahānaumokuākea. Be sure to address the following: Where did the object enter the environment? How was the object transported to Papahānaumokuākea? What processes impacted the object during its travels? What are potential impacts of that marine debris to the environment? How was the object removed from the marine environment? What is the likely fate of this marine debris? What potential impact could this marine debris have on me? What potential impact can I have on marine debris?

Papahānaumokuākea Marine National Monument: Marine Debris Student Worksheet

Name____ Date____

Part 1: Size of a monument

Papahānaumokuākea Marine National Monument (PMNM) is the largest conservation area within the United States. It was established in 2006 and in addition to its National Monument status has also been declared a natural and cultural World Heritage Site by UNESCO. PMNM encompasses 139,797 square miles and extends northwest for 1,200 *nautical miles* starting north of the islands of Ni'ihou and Kaua'i, Hawai'i.



Something of this size is hard to for most people to visualize, especially when it consists mostly of water. In order to better understand the size of this conservation area, compare the length of PMNM to a land-based distance that might be more familiar to you. For this you will need an atlas or access to an online mapping program (such as Google Earth/Maps) that will calculate distance.

1. Convert the length of PMNM (1200 nautical miles) to kilometers. Be sure to show your work! Hint: 1 nautical mile = 1.852 km.

2. Using an atlas or Google Earth/Maps, find a distance between two points that is comparable to the length of PMNM. What are those two points?

3. How many states and/or countries does your land-based calculated distance cross?

4. What might be some issues with trying to manage an area the size of PMNM?

Part 2: Marine debris on the move

Surprisingly, one of the significant issues in PMNM is trash. This is particularly striking since there are no permanent human residents in PMNM. Almost all the trash found in Papahānaumokuākea is generated outside PMNM and introduced into PMNM by visitors, fishing boats and ocean currents in the form of ***marine debris***. Whether through ocean dumping, loss of fishing gear, or litter being washed out to sea in rivers, all the countries in and around the Pacific Ocean are possible sources of marine debris. In order to determine how marine debris moves around in the ocean scientists create models of ocean surface currents and track how debris particles move over long periods of time. Today we will make use of one of these models to investigate where marine debris in Papahānaumokuākea may have originated.

Directions: Using a computer with internet access, navigate to www.adrift.org.au and locate Papahānaumokuākea (note you can click and drag the map to reposition). Next, spend some time exploring possible sources of marine debris to PMNM.

1. List five countries in the Pacific region that are modeled to be sources of marine debris to PMNM.

2. List three countries in the Pacific region that are **not** modeled to be sources of marine debris to PMNM.

3. What are other likely sources of marine debris to PMNM besides the countries you listed above?

4. What are some ways we can prevent marine debris from impacting PMNM and waters closer to home?

Part 3: Beach Walk

Now that you have determined where some of the marine debris might be coming from, it will be important to determine what types of marine debris are actually ending up in PMNM. Unfortunately getting to the islands to survey marine debris is both time consuming and expensive. When faced with situations similar to this, scientists will often turn to ***remote sensing*** techniques to gather data. These techniques allow data to be collected about an object or an environment without the scientist being physically present. Probably the oldest and most well-known form of remote sensing is photography, but other techniques include sonar imaging (radar), multispectral imaging, infrared sensing, and satellite observations, to name just a few. Today we will make use of a series of photographs taken in PMNM to try and determine what types of marine debris actually end up in PMNM.

Directions: Find as many different pieces of marine debris on Lisianski Island (26.056477, -173.961058) or Laysan Island (25.781036, -171.727775) you can and list them below. As you list the pieces of marine debris, classify them by size (see chart on the next page), type of material, and likely source of the debris. Use the data you collect to help answer the questions on the following pages.

Marine Debris Item Type	Item Count	Size Class	Material	Source
Fishing Floats	**#**	**Macro**	**Plastic, rubber, etc.**	**Fishing Vessel**
Totals		**-NA-**	**-NA-**	**-NA-**

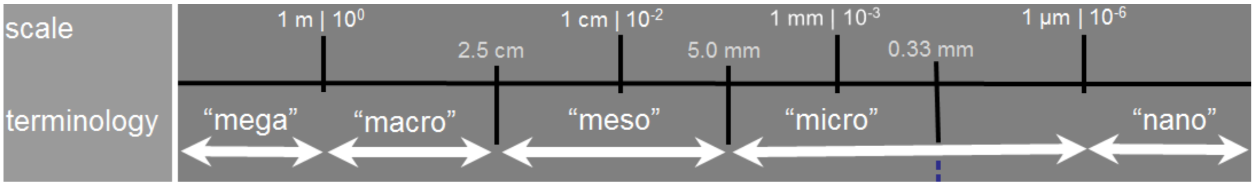


Figure 1: Size classes of marine debris from Lippiatt, S., Opfer, S., and Arthur, C. 2013.

1. What is the dominant size class of marine debris that you found? What percentage of your items fall into this size class?

2. What was the most common material you found in your marine debris survey?

3. What do you think is the most common source of marine debris in PMNM?

Part 4: Characteristics of marine debris

Compare your data with another group of students. As a group discuss and answer the following questions.

1. What characteristics make a material very likely to become marine debris? Does the most common material in your survey have all of these properties?

2. What sizes of marine debris did you NOT find in your visual survey? Where do you think this size of marine debris might be in the environment? How might you go about counting this size of marine debris?

3. List some major impacts (both positive and negative) of marine debris in the environment.

Part 5: Float test

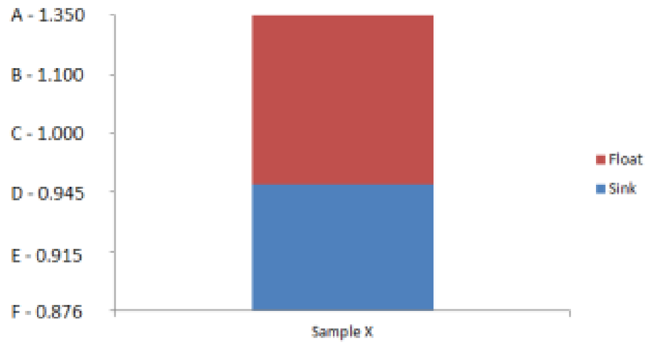
Experimental Data Collection: In your group, use tweezers to test if the plastic pieces float or sink in each of the solutions. You should test each piece of plastic in each solution. Make sure there were no anomalies in your test by testing a second piece of the same type of plastic. This type of testing is called **replicate sampling** and is commonly used by scientists to help ensure accuracy of their sampling data. Make sure you label each sample in the boxes below. You have three pieces of each type of plastic. Make sure you test each separate piece. When you are done use your data to begin making a graph on the following page (**be sure to read the directions!!**).

	Solution A Density: 1.35	**Solution B Density: 1.10**	**Solution C Density: 1.00**	**Solution D Density: 0.945**	**Solution E Density: 0.915**	**Solution F Density: 0.876**
Sample X Replicate 1 (example)	**Floats**	**Float, barely**	**Sinks**	**Sinks**	**Sinks**	**Sinks**

Sample ___ Replicate 1						
Sample ___ Replicate 2						
Sample ___ Replicate 3						

Sample ___ Replicate 1						
Sample ___ Replicate 2						
Sample ___ Replicate 3						

Experimental Data Visualization: Working with your group, use the space provided below to graph your results. Be sure to leave enough room to include data from the rest of the groups in the class (hint: each group will have three observations to graph). Once everyone is done graphing their personal data we will compile data from all groups on the board. Please use a stacked bar type graph that shows the relationship between the density of the solution and where plastic samples floated and sank (see example). Make sure that you label your axes and use the **average** of your observations.



Experimental Data Explanation: Use your data and the class data to answer the following questions. Work with your partner to complete the worksheet.

1. What property of the plastic do you think is responsible for which pieces float and which ones sink?

2. If the plastic pieces you tested were 100 times bigger, would your results be different? Why or why not?

3. Based on your tests, what are the density ranges of your samples? Based on that density range, what type of plastic (by recycle code) is your unknown plastic?

4. If you were told that solution C was fresh water, given what you know from your tests, which plastics (by recycling codes) are most likely to end up in the marine environment? Why do you think that?

5. What physical property of the plastic could change naturally in the marine environment that might cause plastic pieces to sink out of the surface water?

6. What do you think might naturally cause such a change?

Part 6: Marine debris life cycle

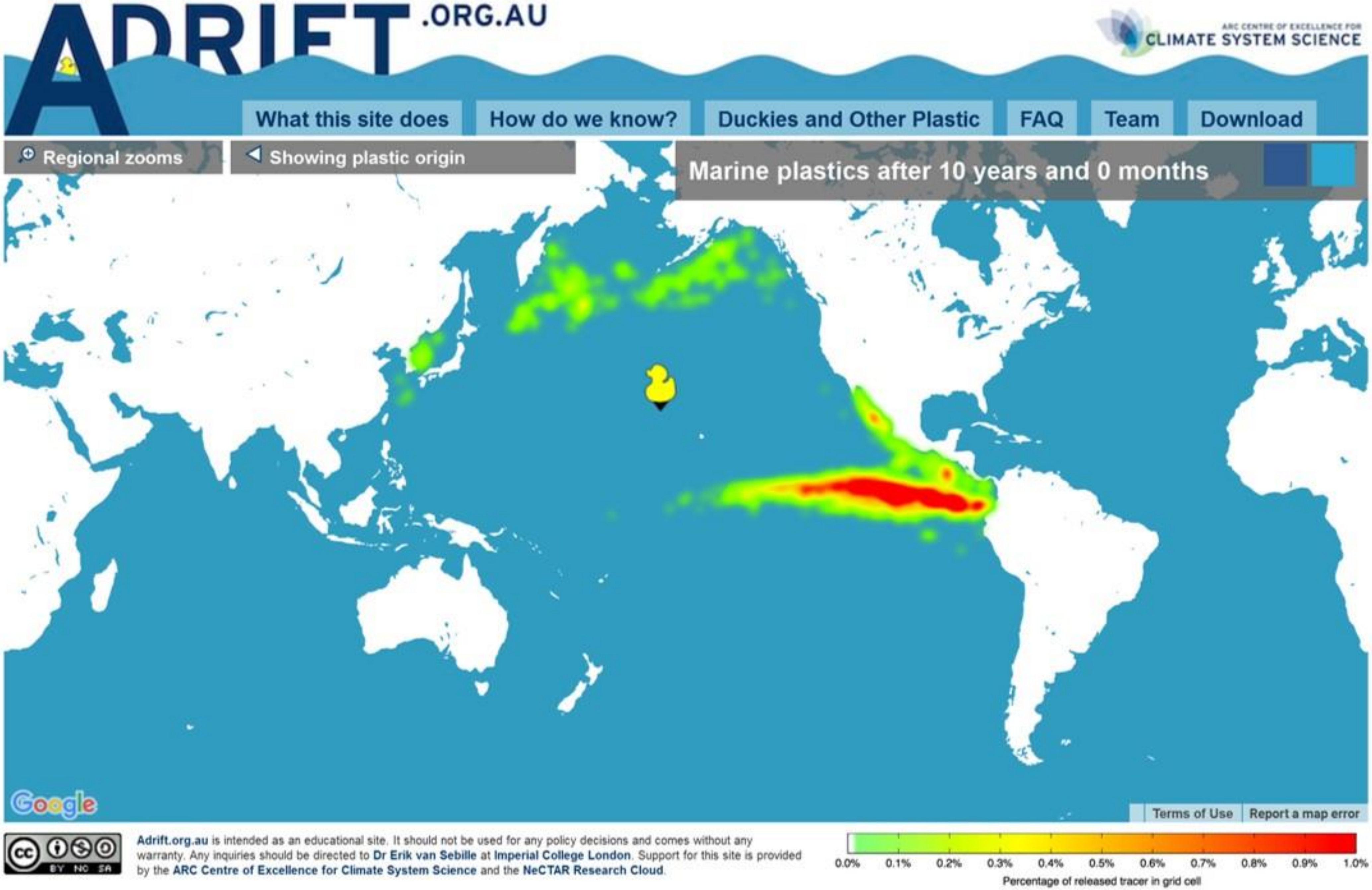
Create a life-cycle model for a piece of marine-debris that you found in Papahānaumokuākea. Be sure to address the following: Where did the object enter the environment? How was the object transported to Papahānaumokuākea? What processes impacted the object during its travels? What are potential impacts of that marine debris to the environment? How was the object removed from the marine environment? What is the likely fate of this marine debris? What potential impact could this marine debris have on me? What potential impact can I have on marine debris?

All About Plastics

Characteristics of Common Plastics

Plastic Type	Name	Properties	Density Range	Common Uses
1 PETE	Polyethylene Terephthalate	Tough, rigid, shatter-resistant, softens if heated	1.38-1.39 g/mL	Soda, water, juice, and cooking oil bottles
2 HDPE	High Density Polyethylene	Semi-rigid, tough, flexible	0.95-0.97 g/mL	Milk and water jugs, bleach bottles
3 PVC	Polyvinyl Chloride	Strong, semi-rigid, glossy	1.16-1.35 g/mL	Detergent bottles, shampoo bottles, shrink wrap, pipes
4 LDPE	Low Density Polyethylene	Flexible, not crinkly, moisture-proof	0.92-0.94g/mL	Garbage bags, sandwich bags, 6-pack rings
5 PP	Polypropylene	Non-glossy, semi-rigid	0.90-0.91 g/mL	Yogurt cups, margarine tubs, screw-on lids/caps
6 PS	Polystyrene	Often brittle, sometimes glossy, often has strong chemical reactions	1.05-1.07 g/mL	Styrofoam, egg cartons, packing pellets, take-out containers

Sources of Marine Debris



Lisianski Island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© 2014 Google
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Laysan Island


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French Frigate Shoals


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Tracking Change over Time: Earth Imagery in the Classroom – Thomas Adamson (SGT Inc.) and Naga Manohar Velpuri (ASRC InuTeq LLC.)

Tracking Change Over Time: Using Landsat Images in the Classroom

Tom Adamson

Stinger Ghaffarian Technologies, Inc., contractor to the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD

Work performed under USGS contract G15PC00012.

Naga Manohar Velpuri, Ph.D.

ASRC InuTeq LLC, contractor to the USGS EROS Center, Sioux Falls, SD

Work performed under USGS contract G13PC00028.

U.S. Department of the Interior
U.S. Geological Survey

Overview

- The Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD
- The Landsat satellites
- Tracking Change Over Time lesson plan
  - Urban growth module
  - River flood module

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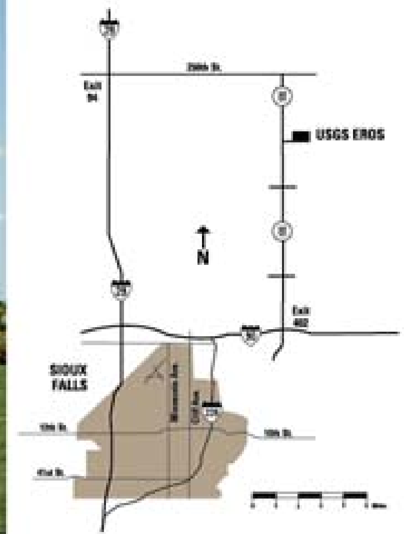
EROS Center

Earth Resources Observation and Science



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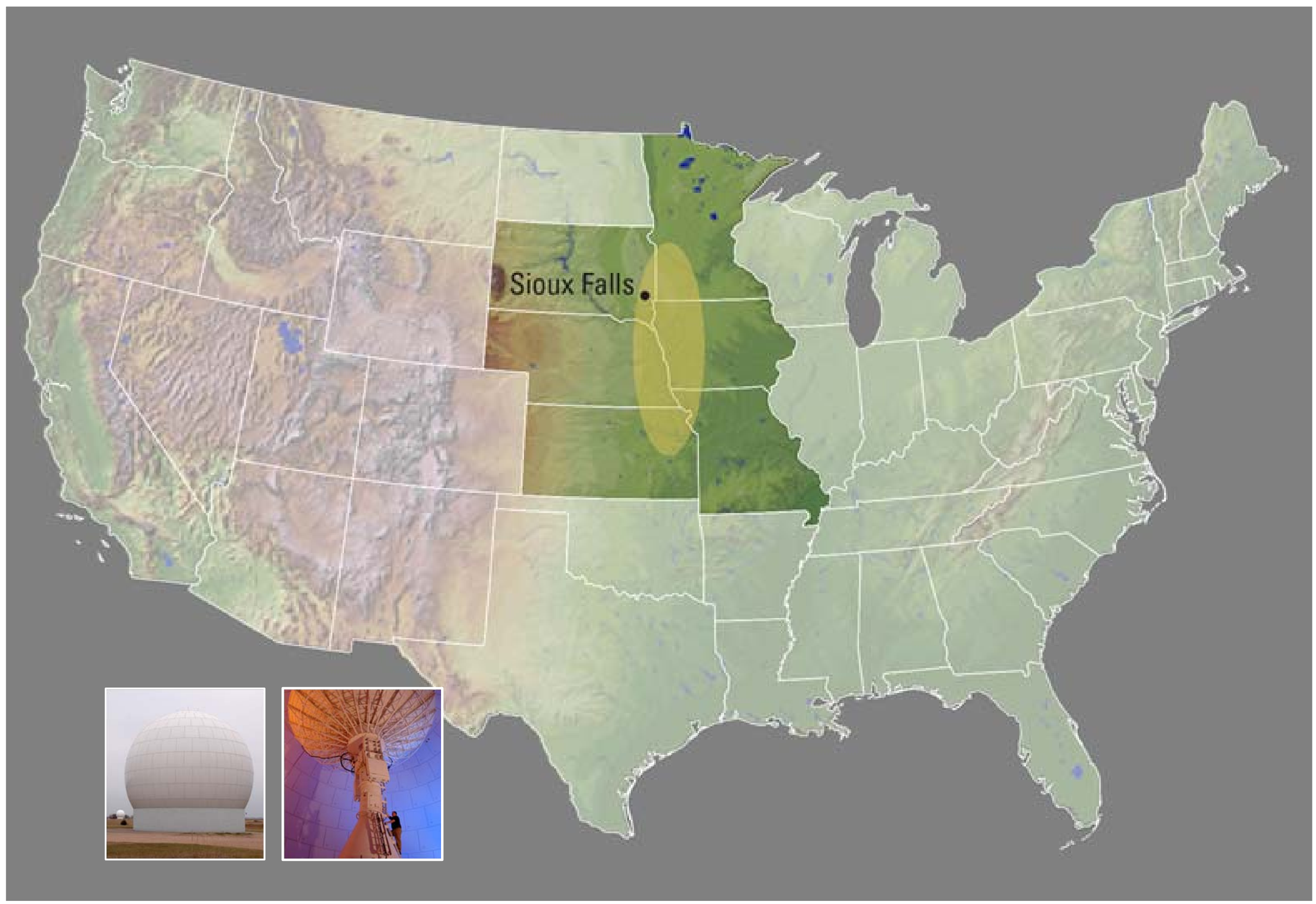
Receiving Data



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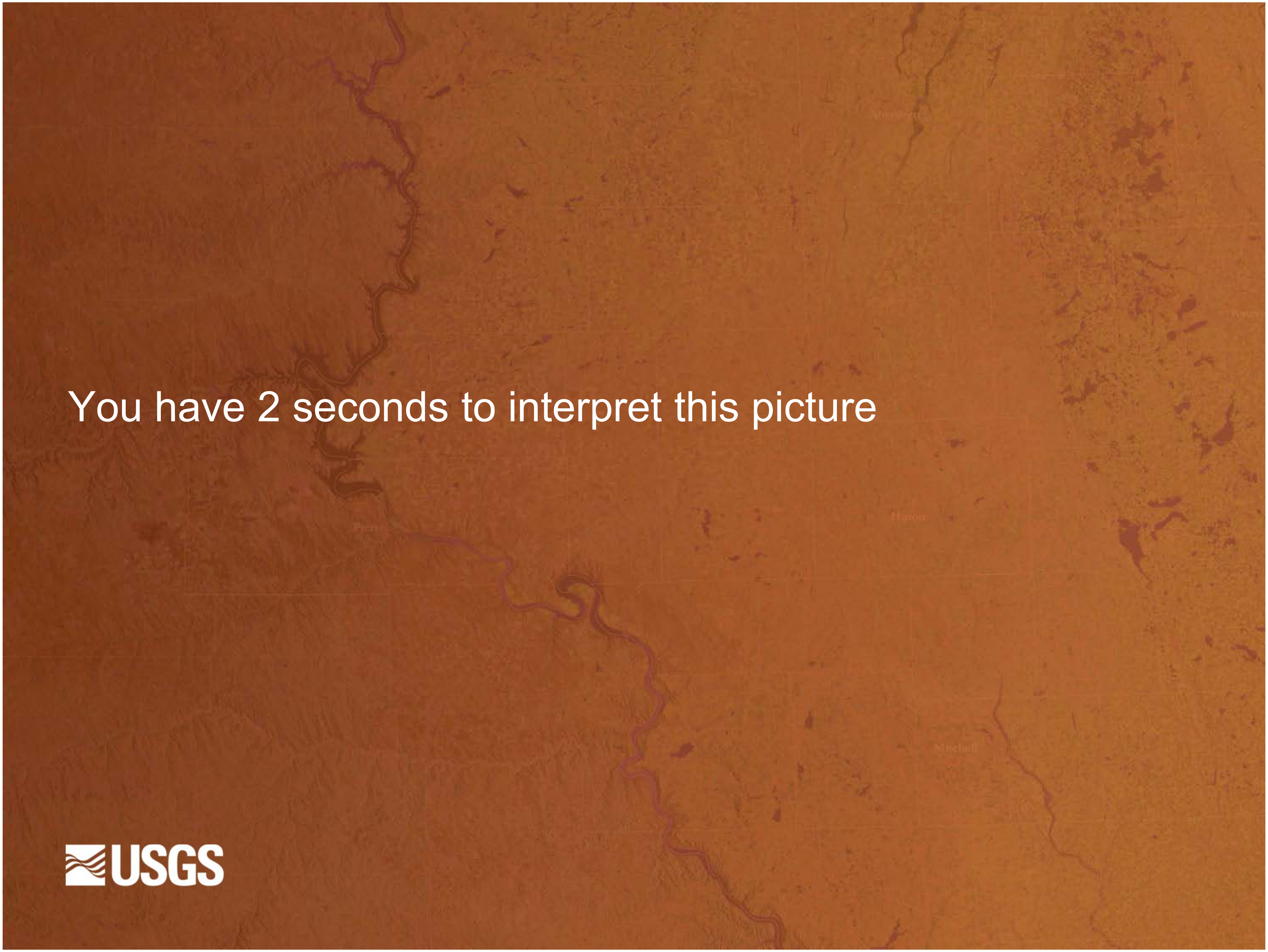
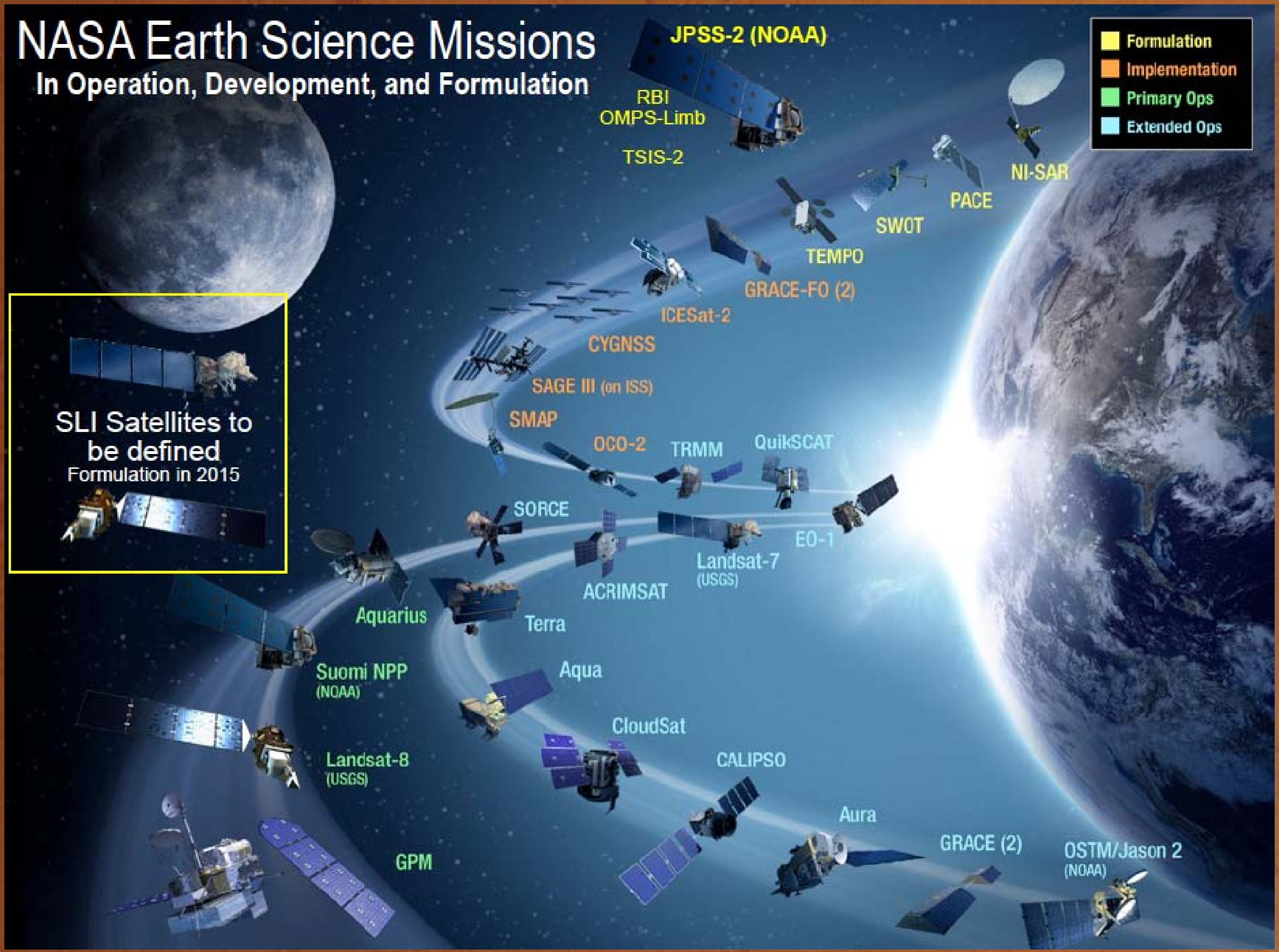
You have 3 seconds to interpret this picture

You have 2 seconds to interpret this picture



Earth Observing Satellites in Space



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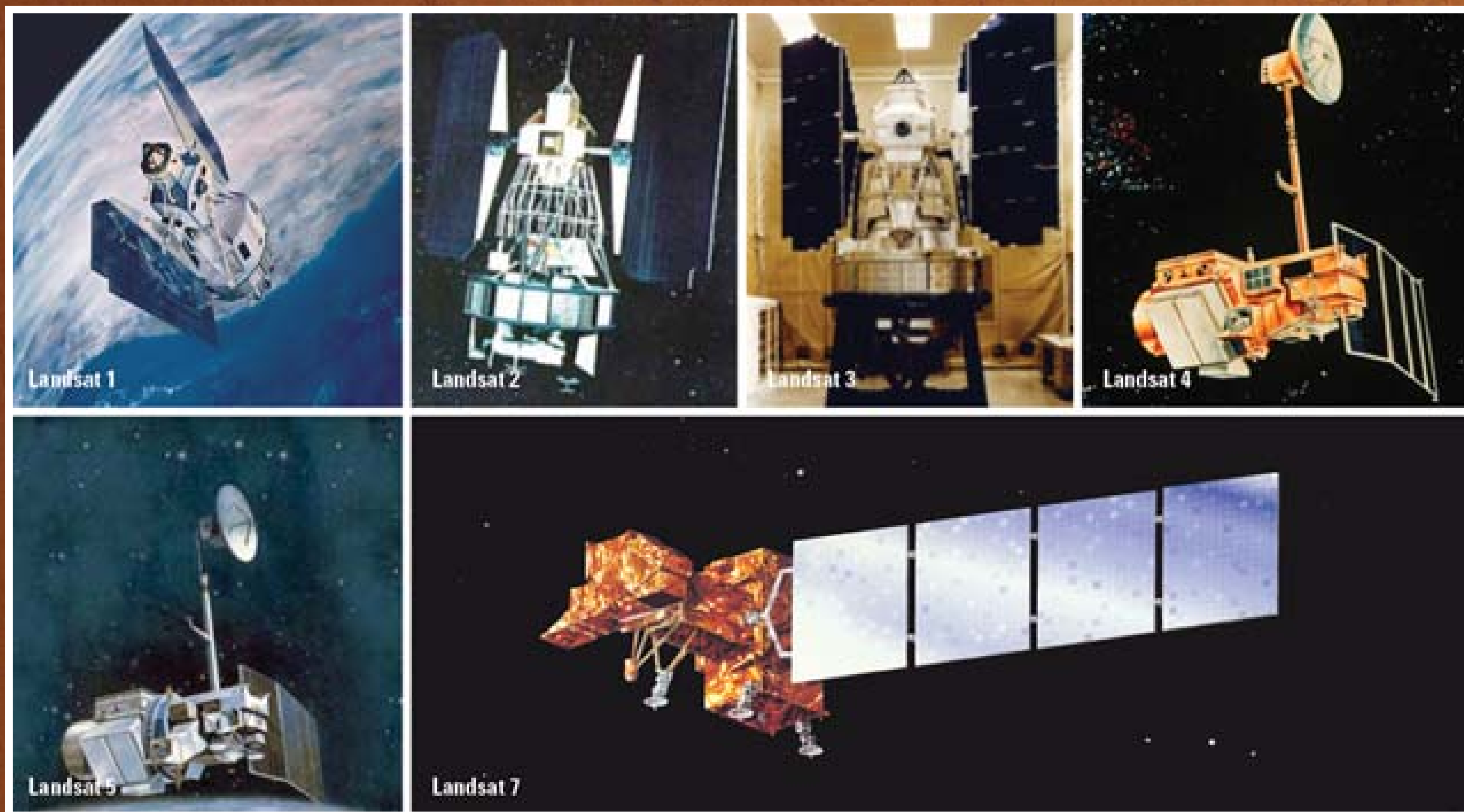
Landsat Program



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Landsat 8

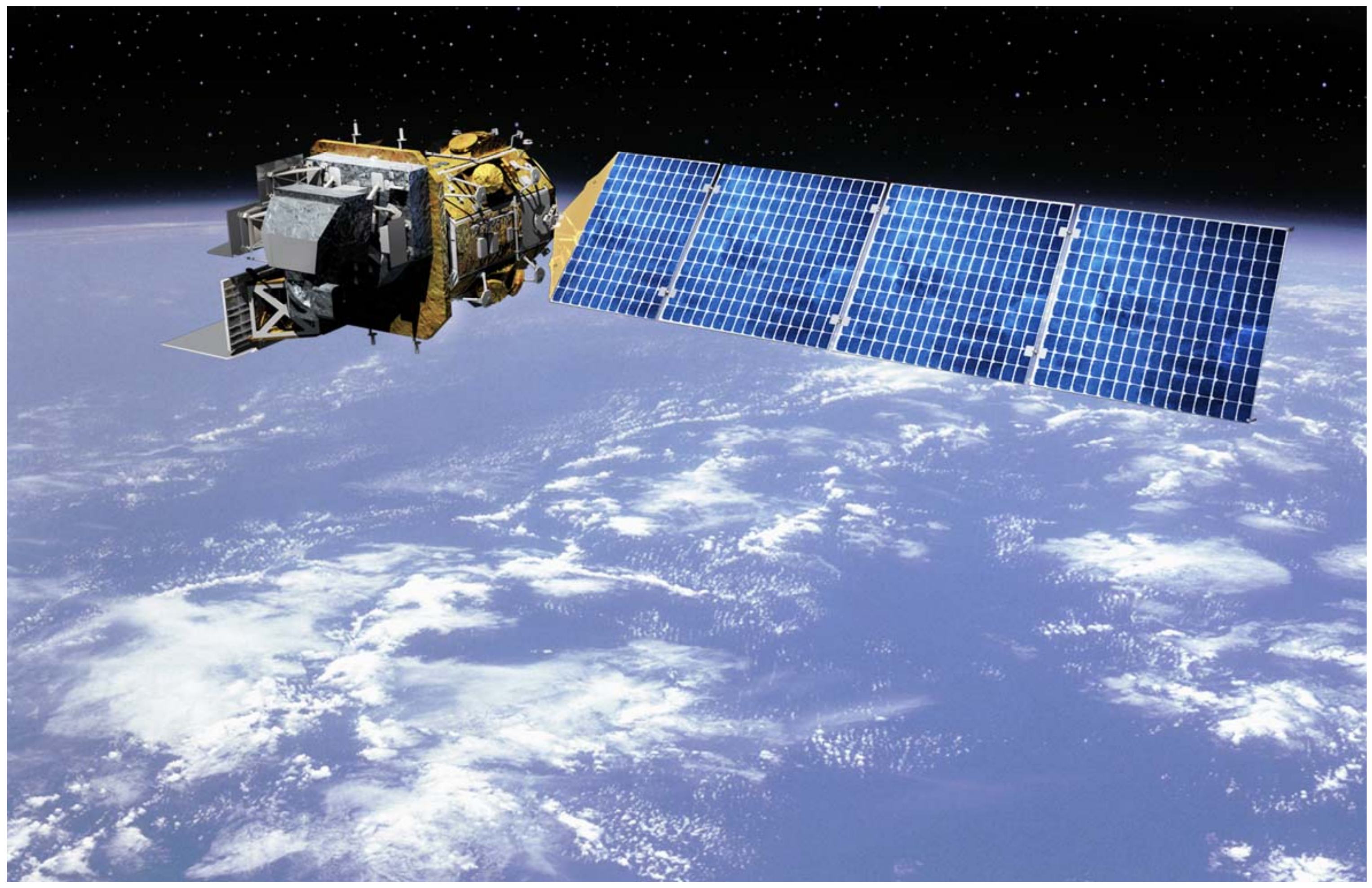


Image courtesy of Orbital Sciences Corporation

USGS

Landsat's orbit

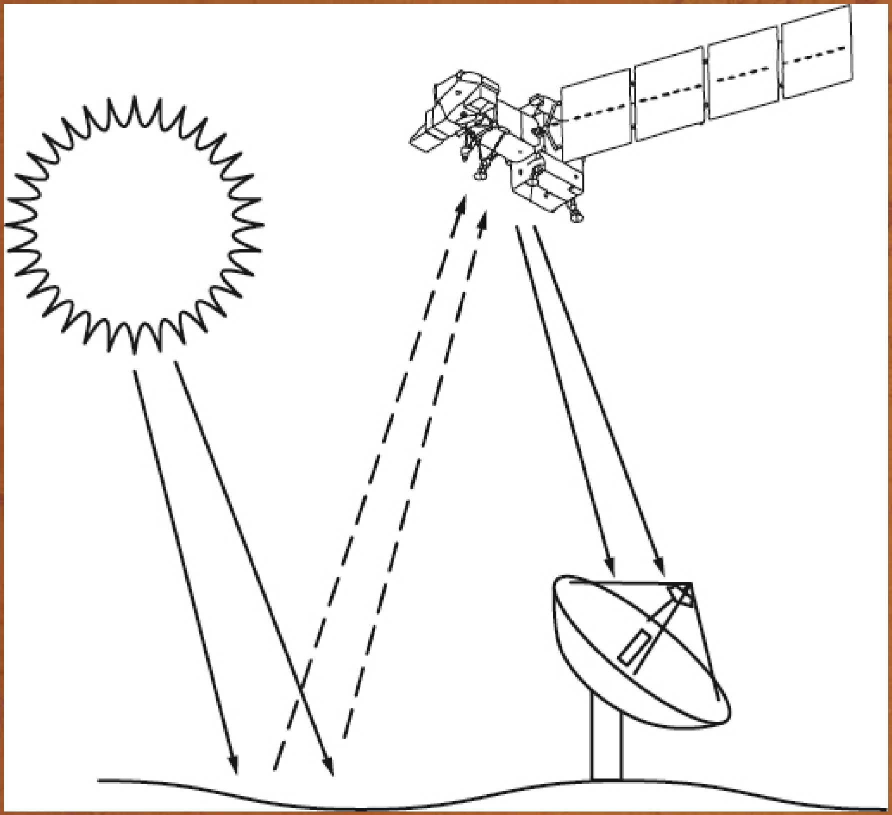
- Orbits at an altitude of 438 miles above the Earth
- 14 orbits per day (every 99 minutes)
- Descending orbit from north to south
- Crosses the equator between 10:00 a.m. and 10:15 a.m. local time on each pass
- Orbits the Earth at 17,000 miles per hour
- Total coverage of Earth's surface occurs every 16 days

USGS


Day 01 06:41

Understanding Remote Sensing

- Remote sensing means observing something from a distance.
- Satellites observe the Earth and help scientists study large tracts of land and how that land changes over time.



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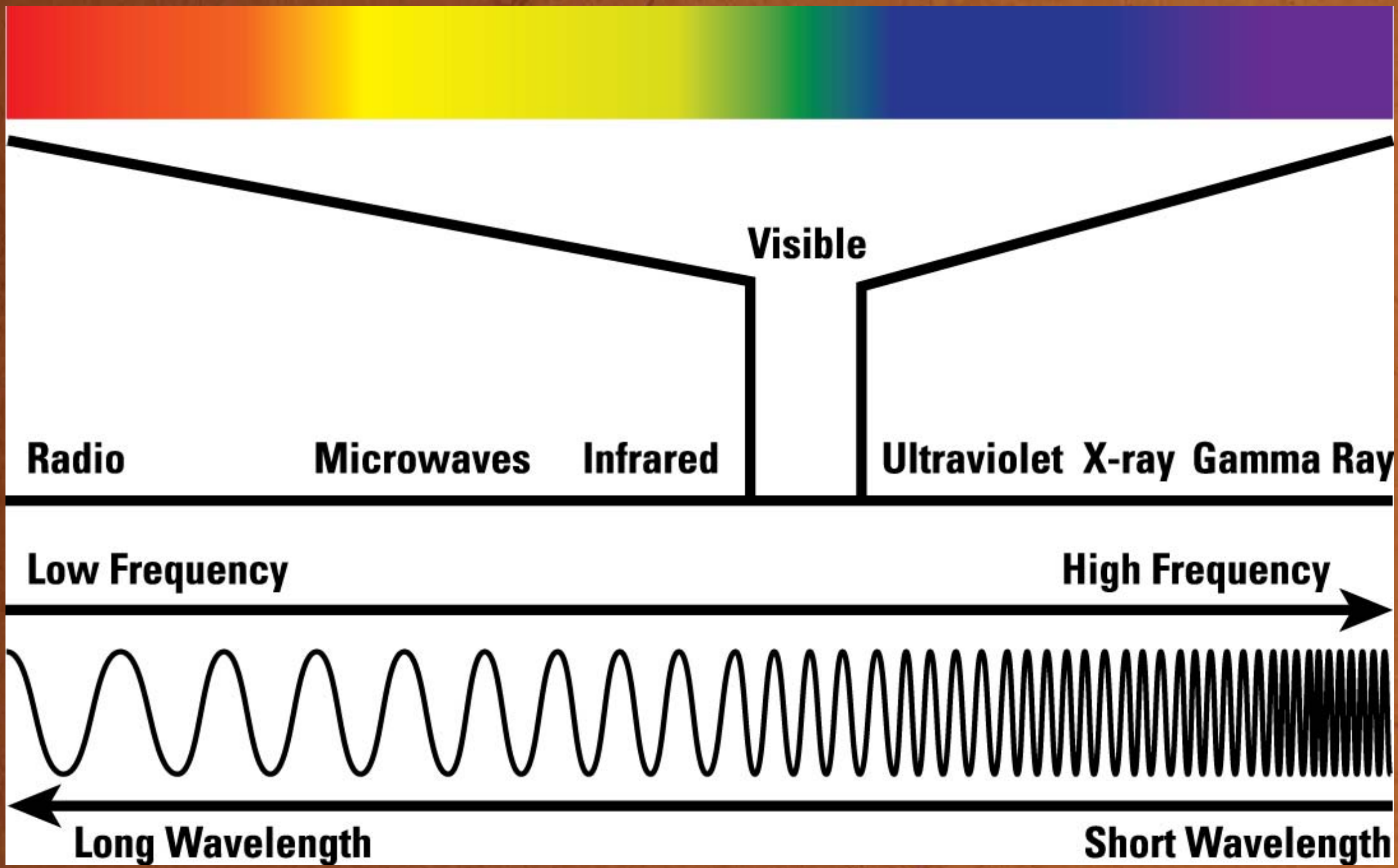
Understanding Remote Sensing

- Electromagnetic spectrum



Bands 3 (red), 2 (green), 1 (blue-green)

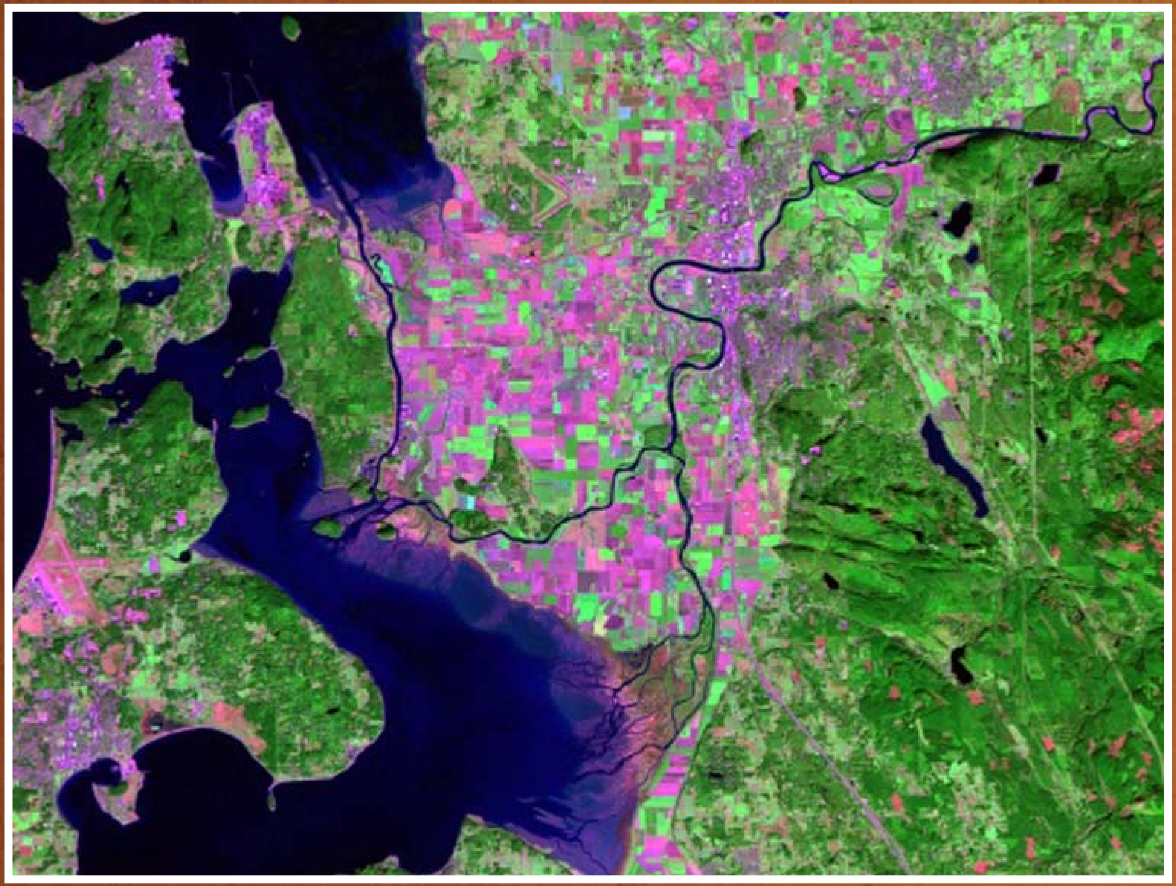
Closest to natural color; used in urban studies and to detect sediment in water.

USGS

Bands 4 (near IR), 3 (red), 2 (green)

Commonly used to indicate vegetation, which appears red because band 4 (near-infrared) is assigned to the color red (vegetation reflects near-infrared light); urban areas = shades of light blue; soils = dark to light brown.

USGS



Bands 7 (mid IR), 4 (near IR), 2 (green)

Actively growing vegetation = bright green; sparsely vegetated areas = oranges and browns; urban areas = varying shades of magenta; dry vegetation = orange; barren soil = pink

USGS

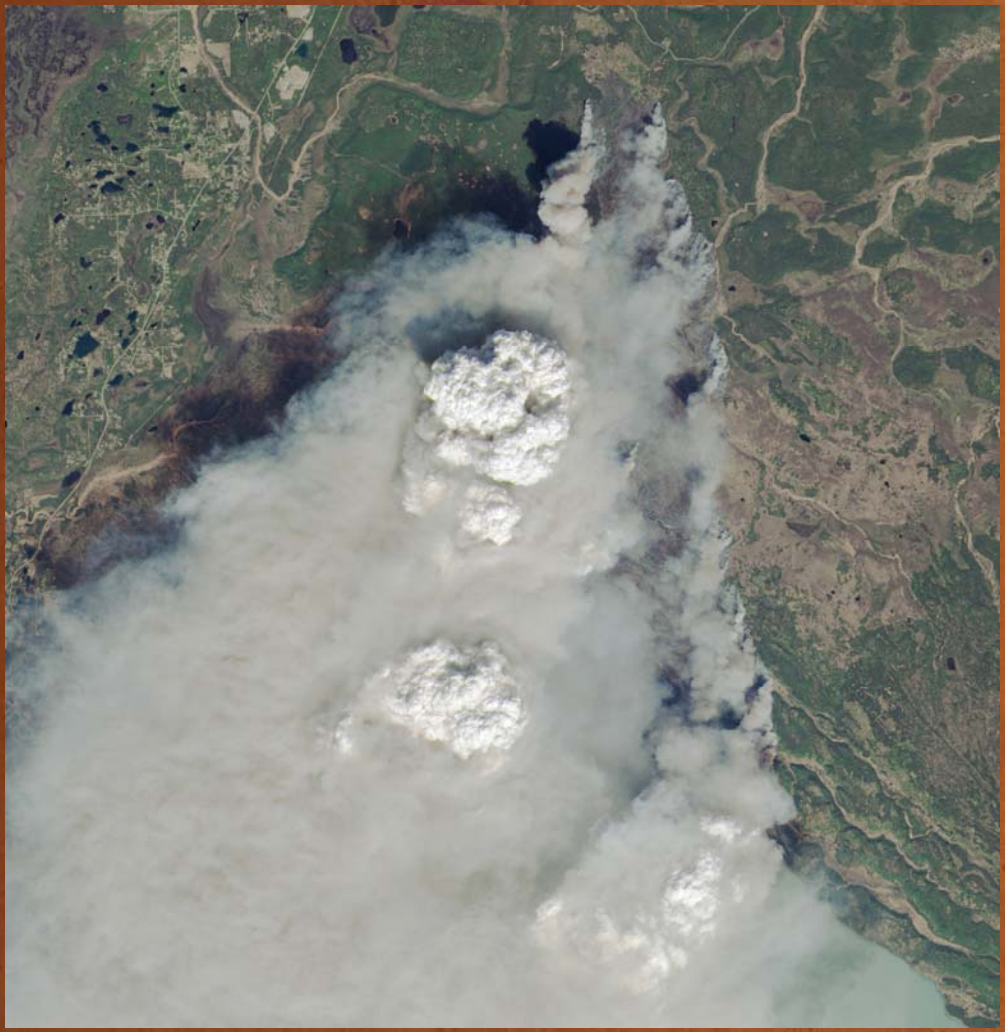
What more can satellite sensors see?

True Color Image
Bands 3 (red), 2 (green), 1 (blue-green)

False Color Image
Bands 4 (near IR), 3 (red), 2 (green)

USGS

What more can satellite sensors see?



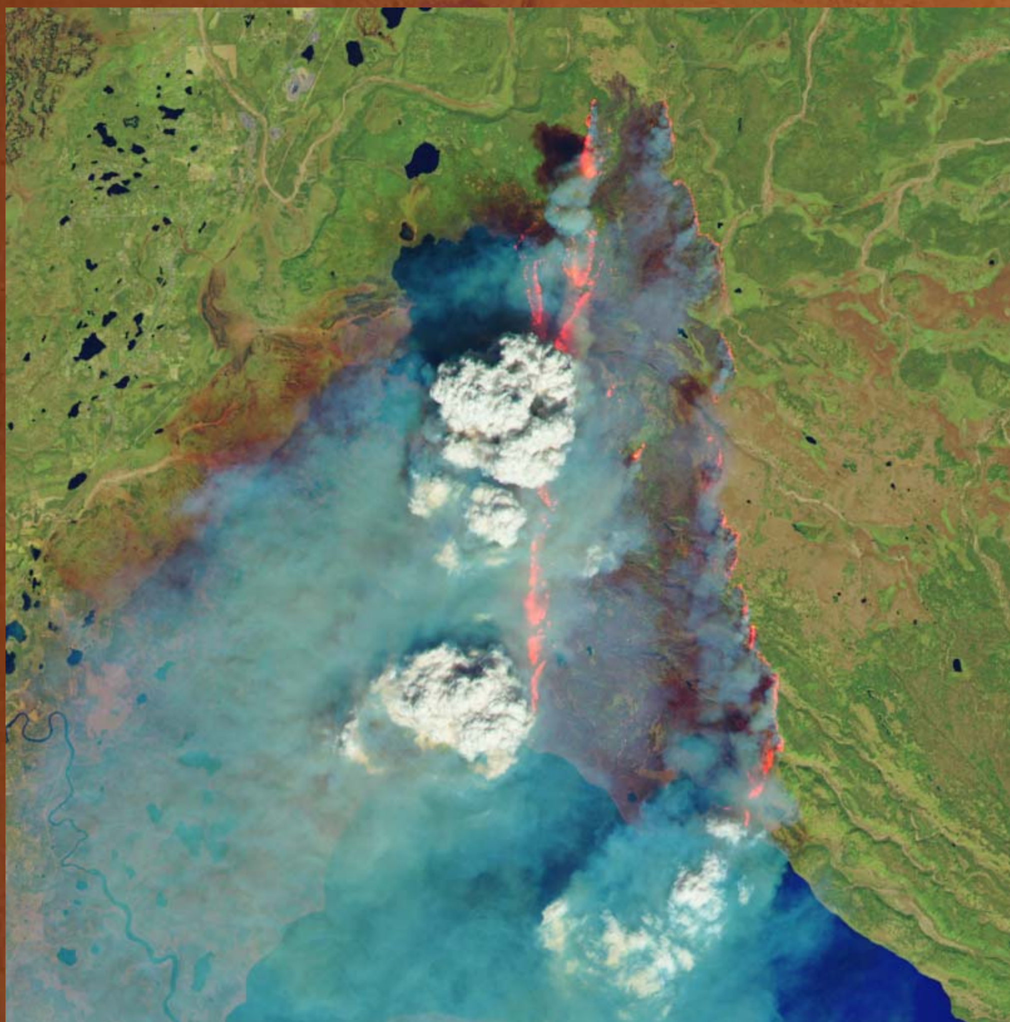
Landsat 8
May 20, 2014

Funny River Fire, Alaska

Bands 4 (red), 3 (green), 2 (blue-green)

USGS

What more can satellite sensors see?



Landsat 8
May 20, 2014

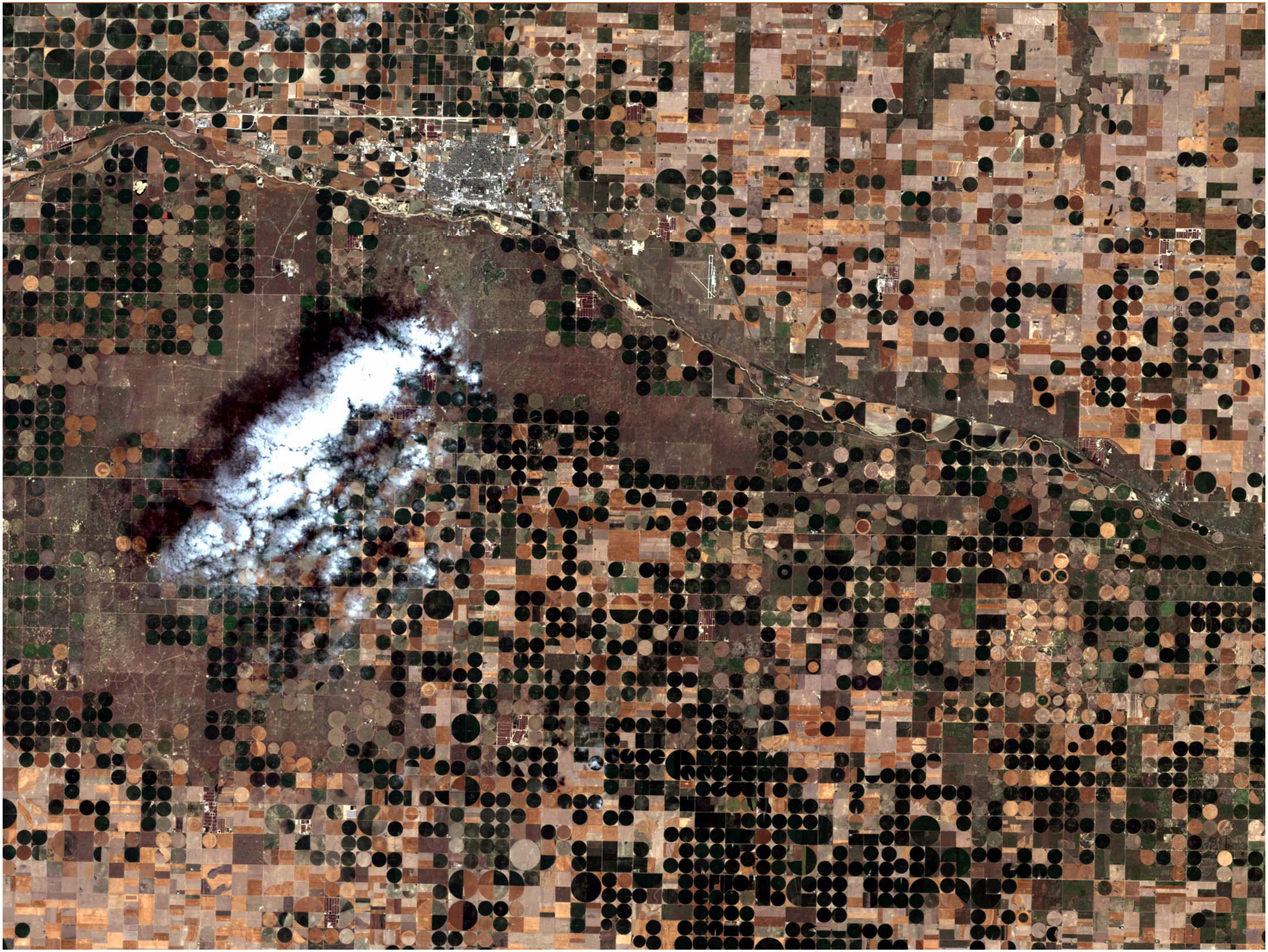
Funny River Fire, Alaska

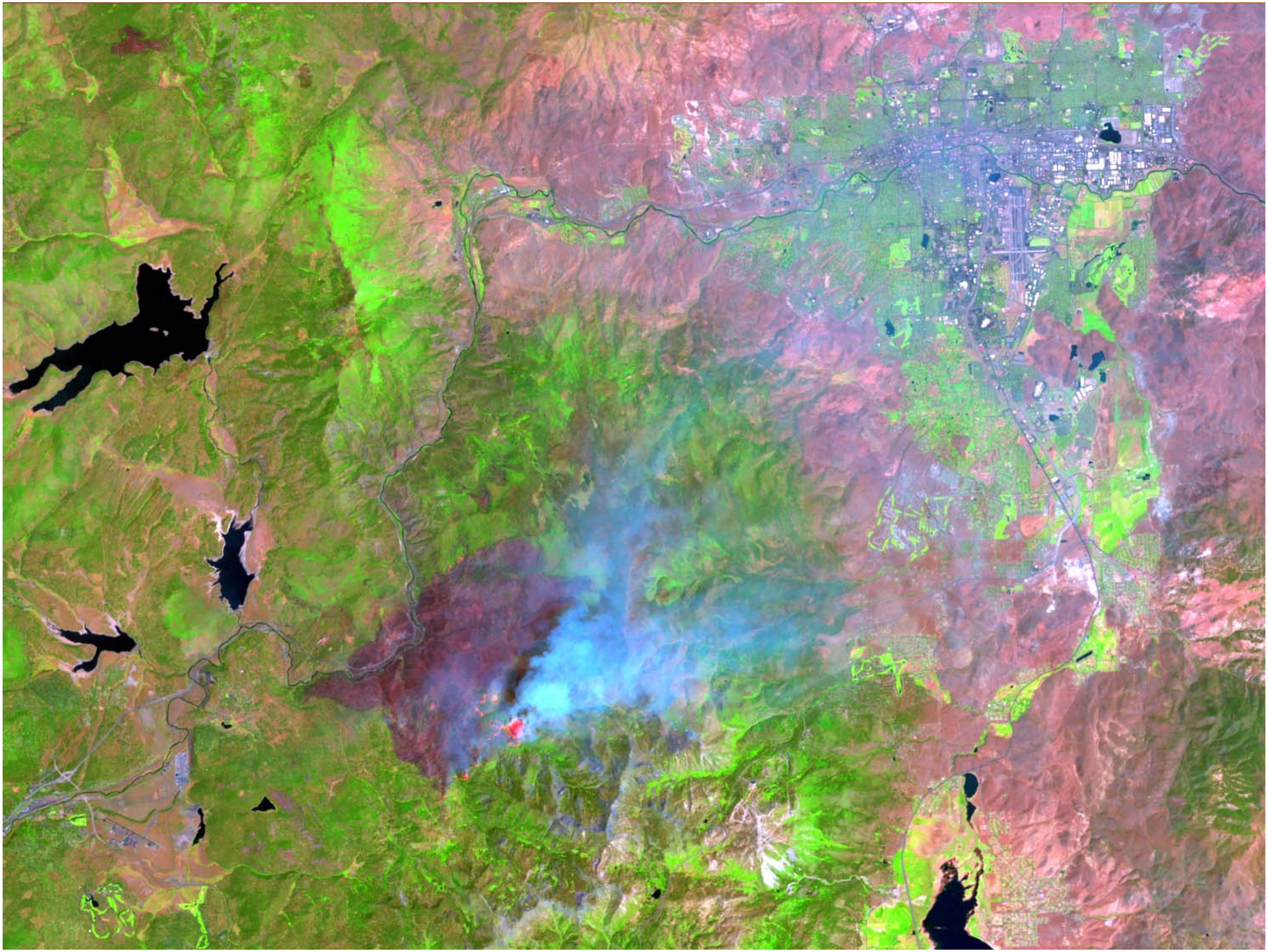
Bands 6 (red), 5 (green), 3 (blue-green)

USGS

What can you see in a satellite image?

- A few more examples…
  - Garden City, Kansas, June 25, 2010
  - Reno, NV, June 19, 2001





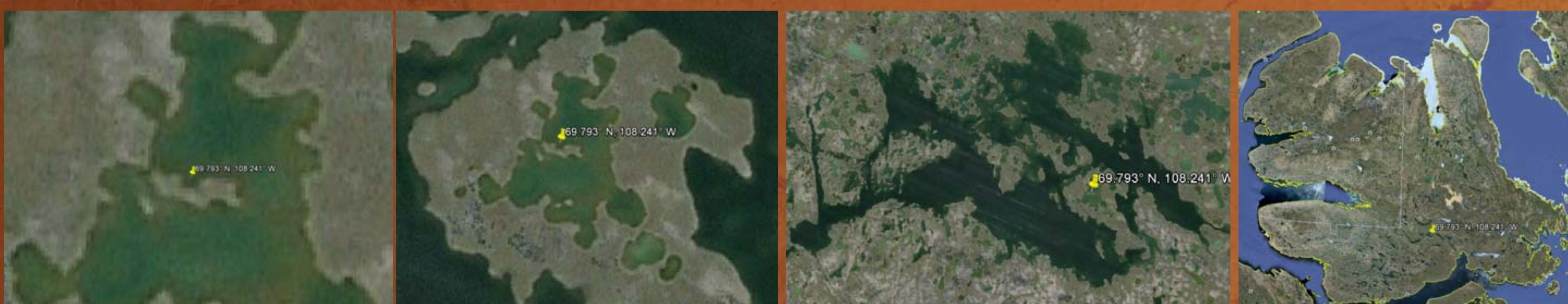
What's a pixel?

- Landsat resolution is 30 meters. That's a little bigger than a baseball diamond.
- Pixel activity…

USGS

Scale in Remote Sensing

- Scale represents the window of perception, the ability of observation and reflects the limitation of knowledge through which a phenomenon may be viewed or perceived. (From Goodchild, 1997 and Marceau, 1999)
- Confused???



Island-in-a-lake-on-an-island-in-a-lake-on-an-island

USGS

Pixel Activity

0	1	2	3	4	5
1					
2					
3					
4					
5					

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0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
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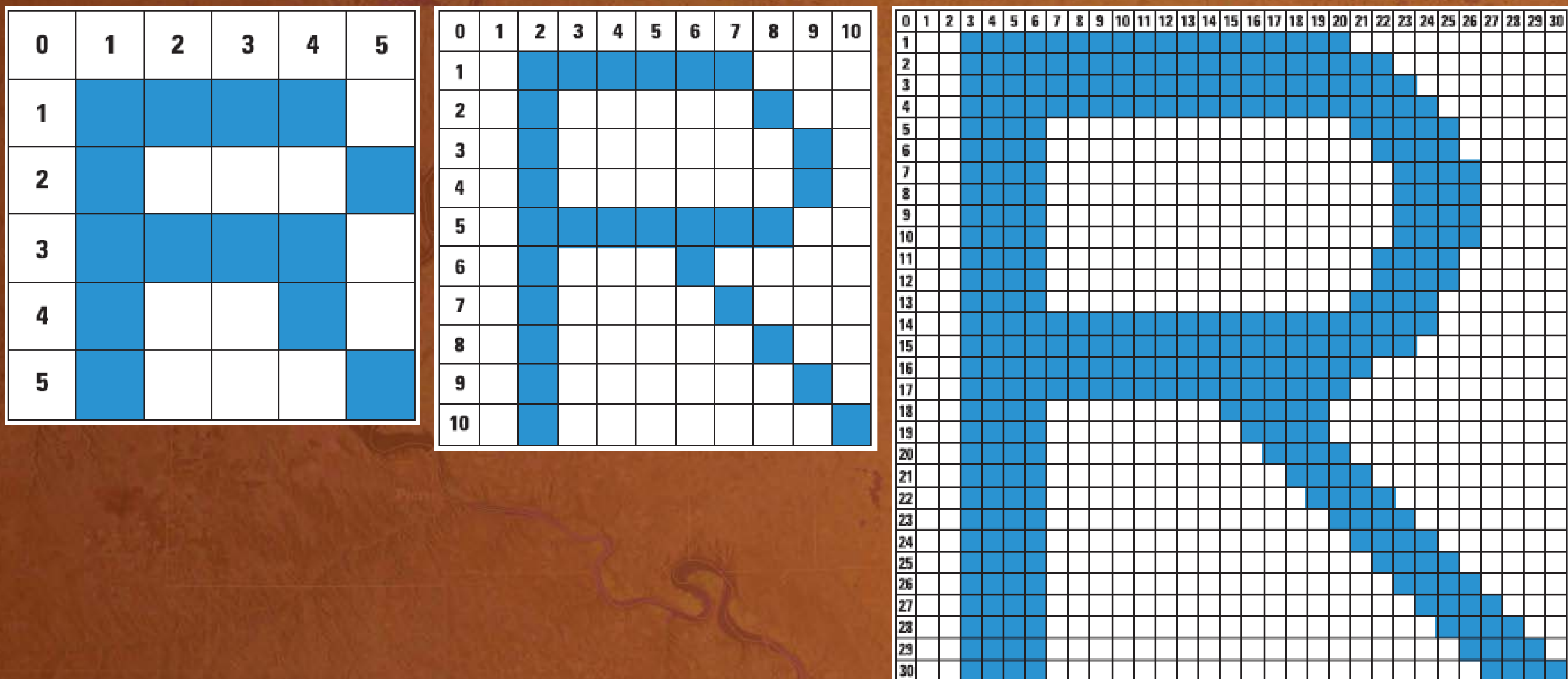
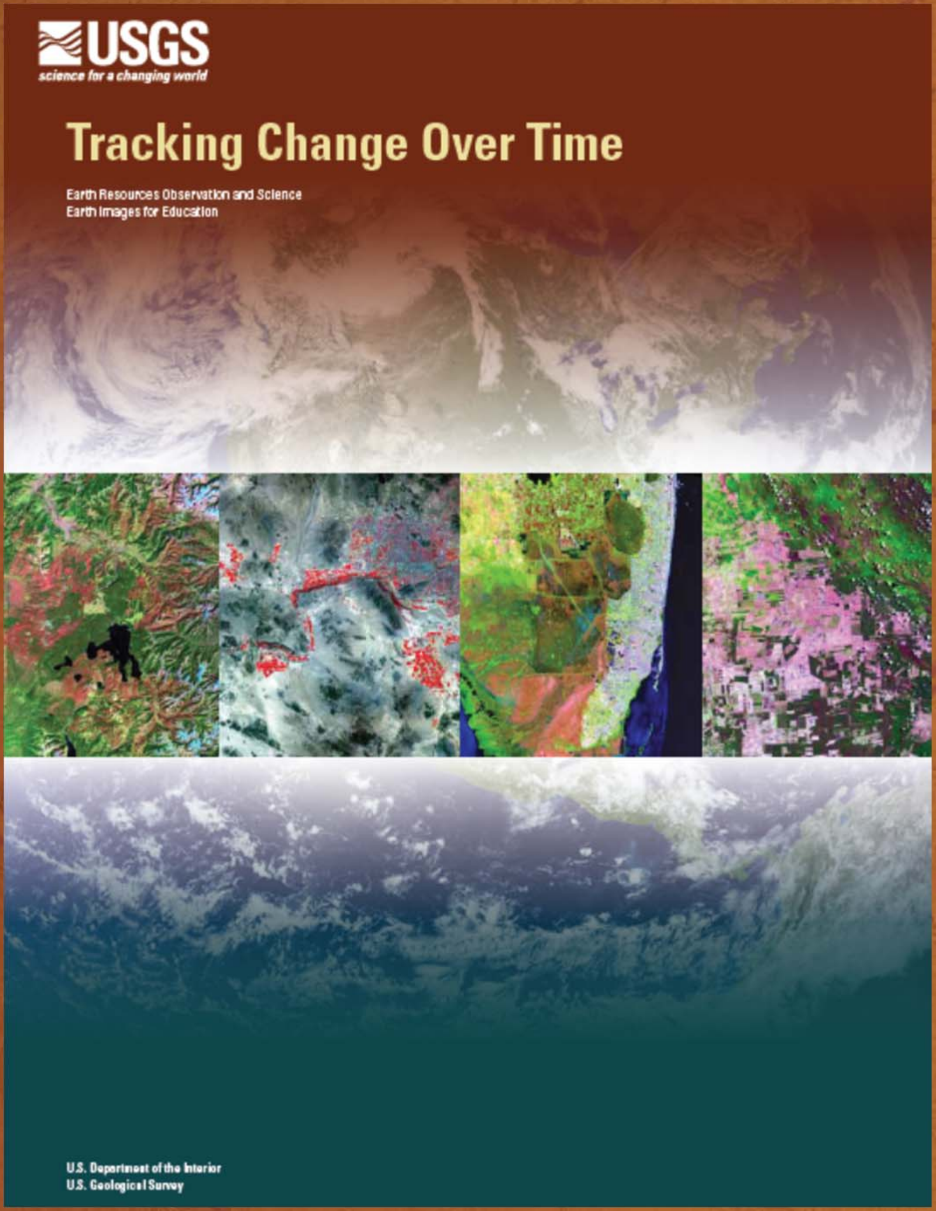
Pixel Activity



Lesson Plan

- For grades 5–8
- Available online at http://eros.usgs.gov/educational-activities



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National Standards

Tracking Change Over Time: Gettin

Time Estimate: one class period, up to 1 hour

Suggested grade levels: 5–8

Materials needed: projection system (computer with projector or SMART Board)

Vocabulary: satellite, Landsat, change pair

National Science Education Standards (NSES)

- Science in Personal and Social Perspective:
    - Populations, resources, and environments
    - Natural hazards

American Association for the Advancement of Science (AAAS) Benchmarks

- **Physical Setting/Processes that Shape the Earth/ Interdependence of Life; Use of Earth's Resources; Weather and Climate (4C/M7)** Human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming, have changed the earth's land, oceans, and atmosphere. Some of these changes have decreased the capacity of the environment to support some life forms.

National Geographic Education Standards

- Standard 14: "Environmental modifications have economic, social, and political implications for most of the world's people. Therefore, the geographically informed person must understand the reasons for and consequences of human modifications of the environment in different parts of the world."

USGS
science for a changing world

Next Generation Science Standards

The standards that apply to the Tracking Change Over Time lesson

4th grade

- Analyzing and Interpreting Data
    - Analyze and interpret data to make sense of phenomena using logical reasoning. (4-ESS2-2)
- ESS3.B: Natural Hazards
    - A variety of hazards result from natural processes (e.g., earthquakes, tsunamis, volcanic eruptions). Humans cannot eliminate the hazards but can take steps to reduce their impacts. (4-ESS3-2)

5th grade

- ESS3.C: Human Impacts on Earth Systems
    - Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments.

Middle School

- Analyzing and Interpreting Data
    - Analyze and interpret data to determine similarities and differences in findings. (MS-ESS3-2)
- PS4.B: Electromagnetic Radiation
    - When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. (MS-PS4-2)
- ESS3.B: Natural Hazards
    - Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events. (MS-ESS3-2)
- ESS3.C: Human Impacts on Earth Systems
    - Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3)
    - Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MS-ESS3-3),(MS-ESS3-4)

http://www.nextgenscience.org/

USGS

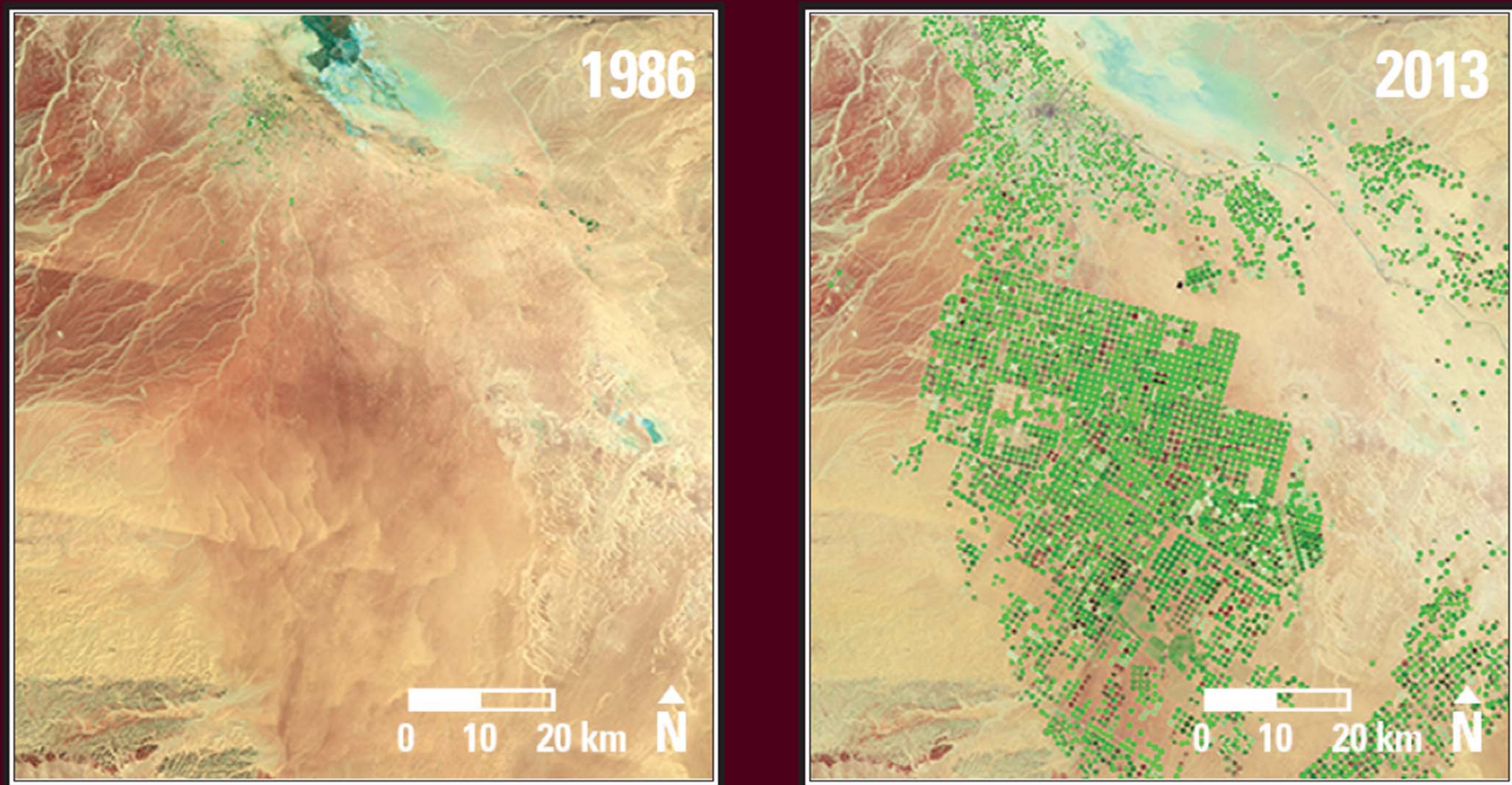
Earthshots

- Change pair images that show significant changes between two dates
- See http://earthshots.usgs.gov/ for more examples of landscape change as seen from the Landsat satellites

USGS

Earthshots

Wadi As-Sirhan Basin, Saudi Arabia



Wadi As-Sirhan Basin, Saudi Arabia 1986-2013

These two images reveal the effects of center-pivot irrigation systems in Saudi Arabia's desert region known as Wadi As-Sirhan. This landscape has been transformed from wasteland into cropland covered with circular green fields. The fields are watered with groundwater, which in this arid region is a nonrenewable resource.

Date	Satellite	Bands	Res	Path	Row
Feb. 2, 1986	Landsat 5 TM	7,4,2	30 m	172	39
Aug. 23, 2013	Landsat 8 OLI	7,5,3	30 m	172	39

Earthshots: Satellite Images of Environmental Change

The U.S. Geological Survey Earth Resources Observation and Science (EROS) Center archives data from the Landsat satellites (1972–present). Earthshots presents environmental changes using Landsat images.

http://earthshots.usgs.gov

09/13

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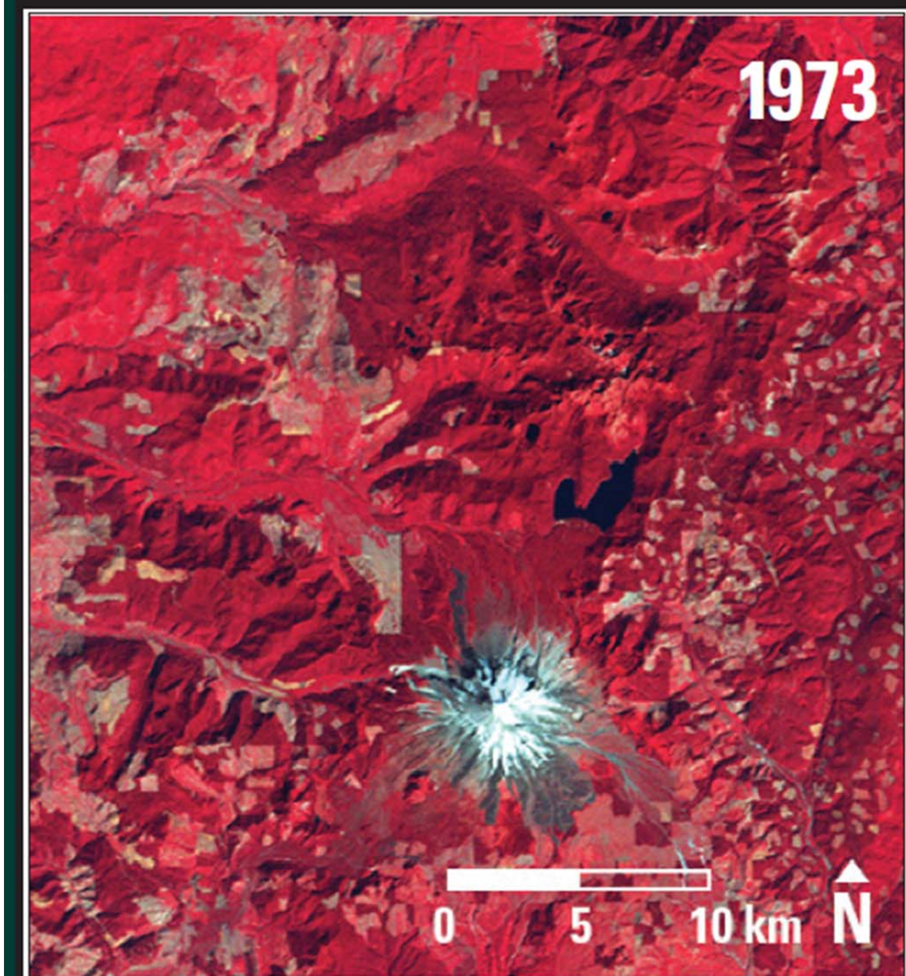
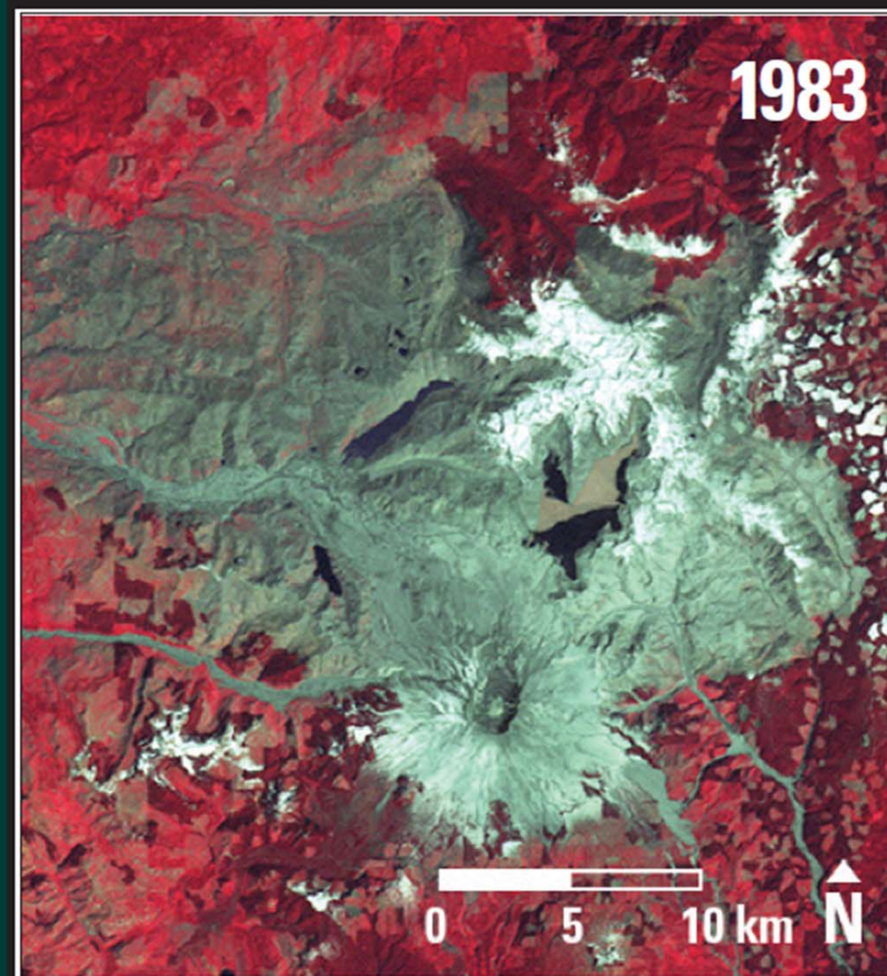
Earthshots

Mount St. Helens, Washington, USA





Mount St. Helens, Washington, USA 1973-1983

The eruption of Mount St. Helens on May 18, 1980, destroyed 150 square miles of forest, blew ash 15 miles into the air, and killed 60 people. The mountain's elevation dropped from 9,677 feet to 8,364 feet. Forest appears red; ash and mud appear gray. Ice and snow are white, and water is black.

Date	Satellite	Bands	Res	Path	Row
Sept. 15, 1973	Landsat 1 MSS	7,5,4	79 m	49	28
May 22, 1983	Landsat 4 MSS	4,2,1	79 m	46	28

Earthshots: Satellite Images of Environmental Change

The U.S. Geological Survey Earth Resources Observation and Science (EROS) Center archives data from the Landsat satellites (1972–present). Earthshots presents environmental changes using Landsat images.

http://earthshots.usgs.gov

Using MultiSpec

- Developed at Purdue University
- Distributed without charge
- https://engineering.purdue.edu/~biehl/MultiSpec/index.html

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Band combinations

Landsat 5 and 7	
Band	Portion of S
1	Blue-green
2	Green
3	Red
4	Near-infrare
5	Mid-infrared
6	Thermal infr
7	Mid-infrared

Landsat 8		
Band	Portion of Spectrum	Wavelength (micrometers)
1	Coastal aerosol	0.43–0.45
2	Blue	0.45–0.51
3	Green	0.53–0.59
4	Red	0.64–0.67
5	Near-infrared	0.85–0.88
6	shortwave infrared 1	1.57–1.65
7	shortwave infrared 2	2.11–2.29
8	Panchromatic	0.50–0.68
9	Cirrus	1.36–1.38
10	Thermal infrared 1	10.60–11.19
11	Thermal infrared 2	11.50–12.51

USGS

Commonly used band combinations

Landsat 5 Landsat 7	Landsat 8	Description
3,2,1	4,3,2	Closest to natural color: urban studies, sediment
4,3,2	5,4,3	Commonly used to indicate vegetation, which appears red
7,4,2	7,5,3	Actively growing vegetation=bright green; barren soil=pink
4,5,1	5,6,2	Vegetation=red, brown, orange, yellow; soil=green, brown
5,4,3	6,5,4	Vegetation=bright green; soil=pale lavender

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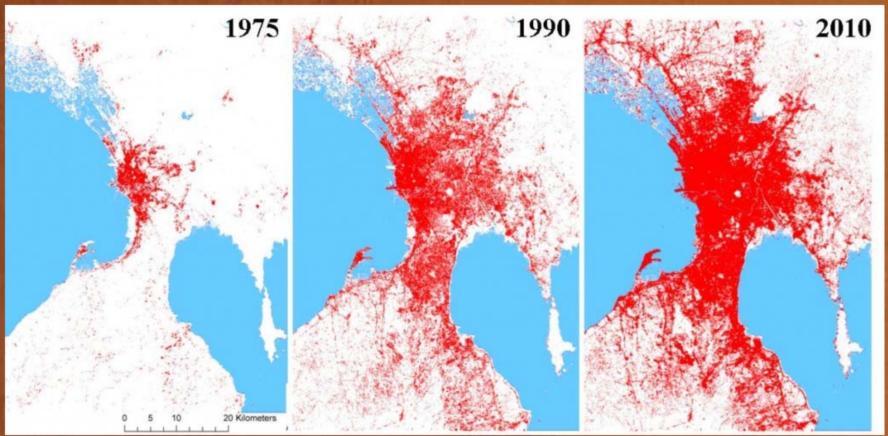
Urban Change Module

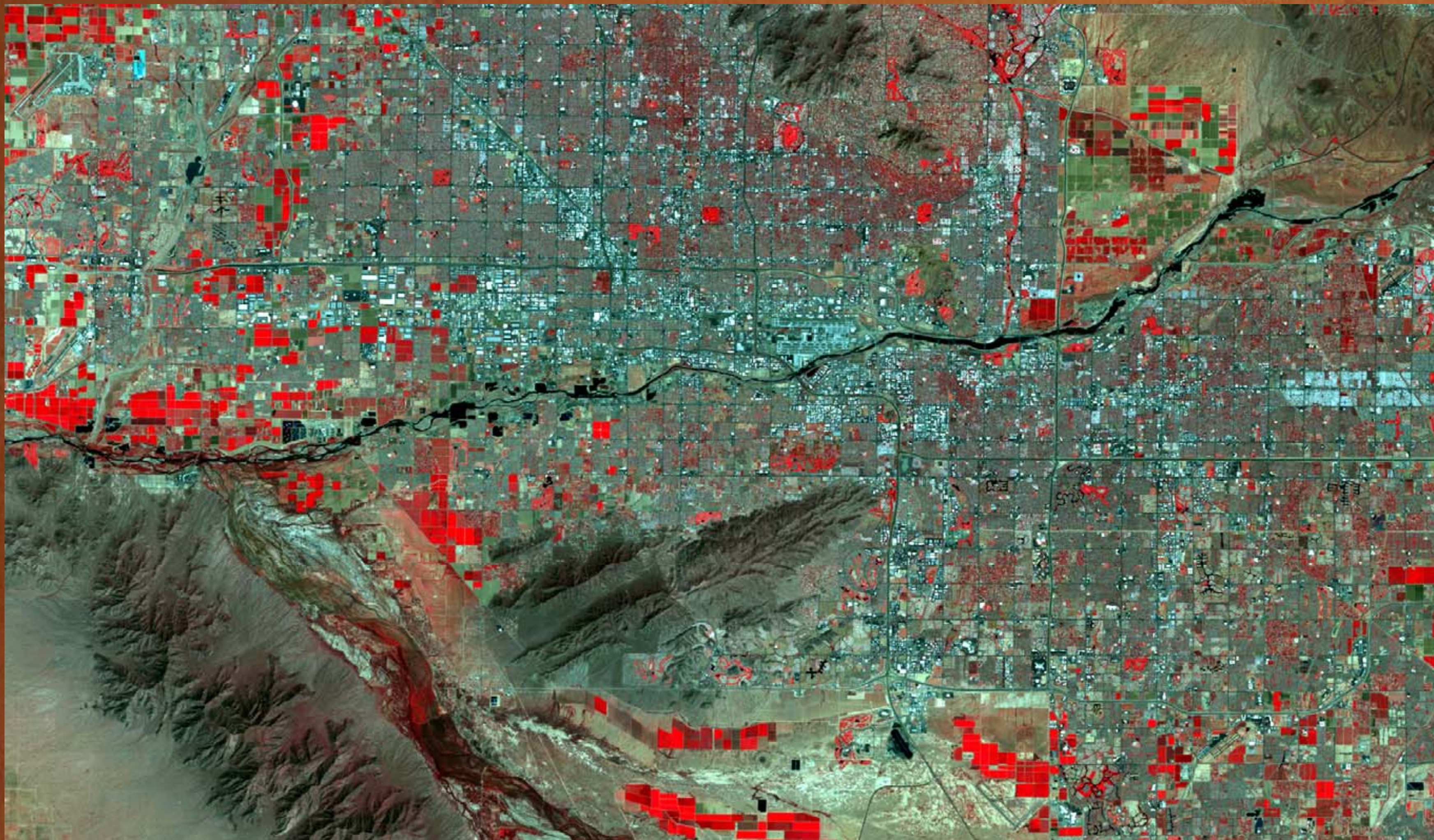
- Globally, more people live in urban areas than in rural areas
  - In 1950 → 30% of people lived in urban areas
  - By 2014 → 54% and by 2050 → 66% are projected to live in urban areas.
- Urbanization is defined by the United Nations as movement of people from rural to urban areas
- The urbanization in recent past is a global phenomenon, but not even two cities in the world became identical.



Urban growth analysis of Manila, Philippines.
*Source: DLR-DFD (*Taubenböck and Esch, 2011)

USGS

Urban Area Change—Phoenix



USGS

Scavenger Hunt

- See if students can locate various features in one of the images.

Lesson Extension: Scavenger Hunt

Using any of the three entire images, send students on a scavenger hunt to find the following features or structures: (answers for the teacher provided in lat-long)

Using any of the three entire images, see if you can find the following features or structures. Provide the latitude/longitude coordinates of the locations.

- Automobile Racetrack (Phoenix Int'l Raceway is at roughly 33.375°, –112.311°)
- Stadium (hint: structure has a white roof) (University of Phoenix Stadium is at 33.527°, –112.263°—bright white of the roof surrounded by dark parking lots and a couple of small areas of grass; grass is red in 4,3,2 band combination. This is only in the 2010 image.)
- Lake (33.569°, –111.525° is Saguaro Lake, formed behind a dam on the Salt River. Another reservoir, Lake Pleasant, is at 33.882°, –112.280°)
- Highway or freeway interchange (there are several—a noticeable one is at 33.297°, –111.972°)
- Crop fields that are circles (these are farms with center-pivot irrigation, 33.209°, –111.541°)
- A place where the edge of a residential area is right up against desert (in the 2010 image, at about 33.346°, –111.589°, is one area. There are probably others and in the other years too.)
- Where you would likely get a good view of agriculture from a highway (one spot is 32.917°, –112.910°—ask students, how would you know this for sure?)

USGS

University of Phoenix Stadium

1991–2010

USGS

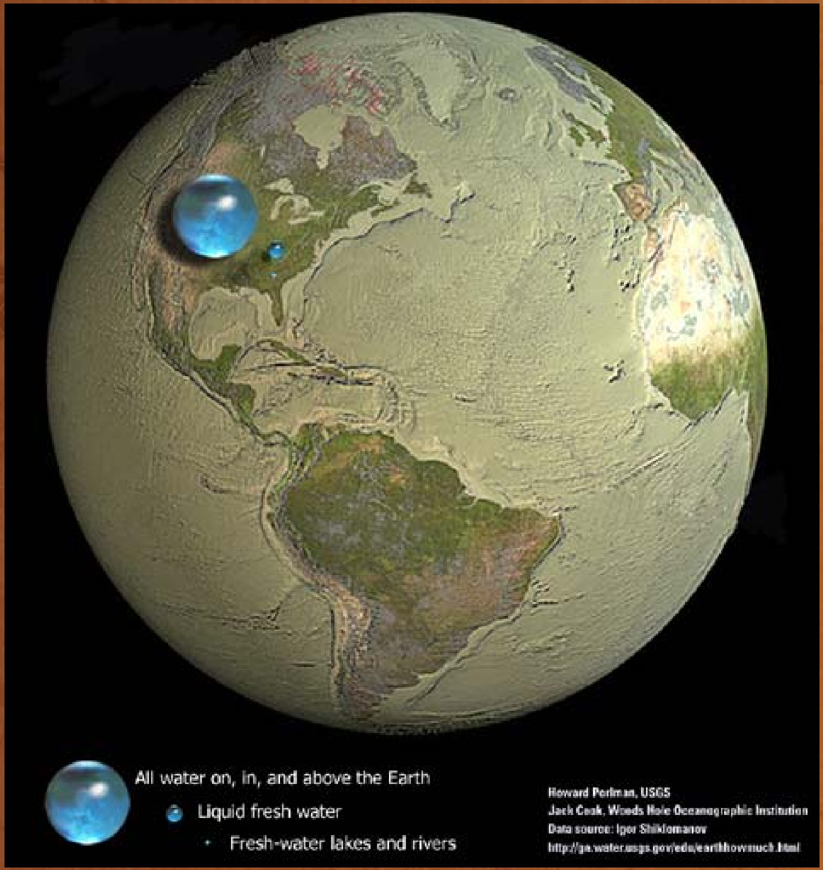
science for a changing world

Las Vegas growth: 1972–2015

U.S. Department of the Interior
U.S. Geological Survey

Flood Module

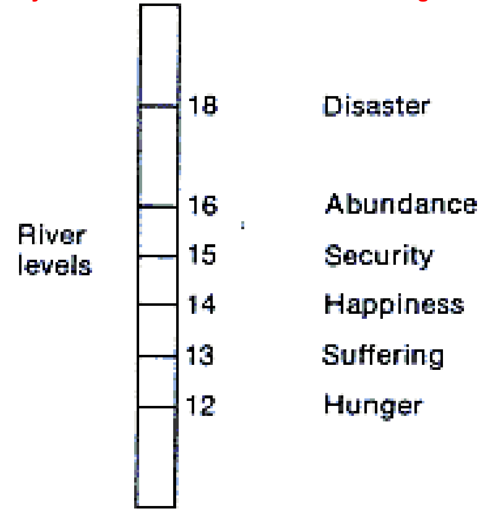
- Why study hydrology/water resources?



USGS

Humans have been monitoring water levels for millennia

Pliny-the-elder's classification of river stages



Eagleson (1994)- Advances in Water Resources

USGS

River Cutoff

New Orleans, LA

Educational Resources at USGS

- EarthNow: http://earthnow.usgs.gov
- Earthshots: http://earthshots.usgs.gov
- USGS Education: http://education.usgs.gov/index.html

- Contact me with any questions
- tadamson@usgs.gov

USGS

Conserving our nonrenewable resources: Developing a theme-based NGSS-aligned integrated science unit using the Mi-STAR method – Emily Gochis, Stephanie Tubman, Luke Bowman, Steve Mattox, Doug Oppliger, and Robert Handler (Michigan Technological University – MiSTAR Program)

Mi-STAR: Michigan Science Teaching and Assessment Reform

Workshop Presenters:

Emily Gochis	Luke Bowman
Stephanie Tubman	Doug Oppliger
Robert Handler	Steve Mattox

All Lesson Plans and Handouts can be found on the **Mi-STAR Website at:**
http://mi-star.mtu.edu/GIFT2015

THE HERBERT H. AND GRACE A. DOW FOUNDATION

Mi-STAR
Michigan Science Teaching and Assessment Reform

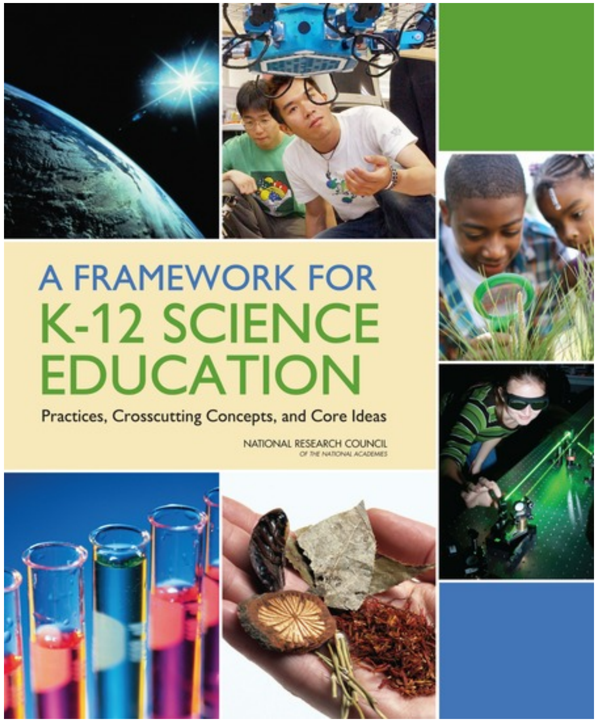
Mi-STAR is…

- A partnership to reform STEM education

Mi-STAR is…

Motivated by a vision for the future in which science is taught and learned as an integrated body of knowledge that can be applied to address real-world problems and phenomena.

NEXT GENERATION SCIENCE STANDARDS
For States, By States

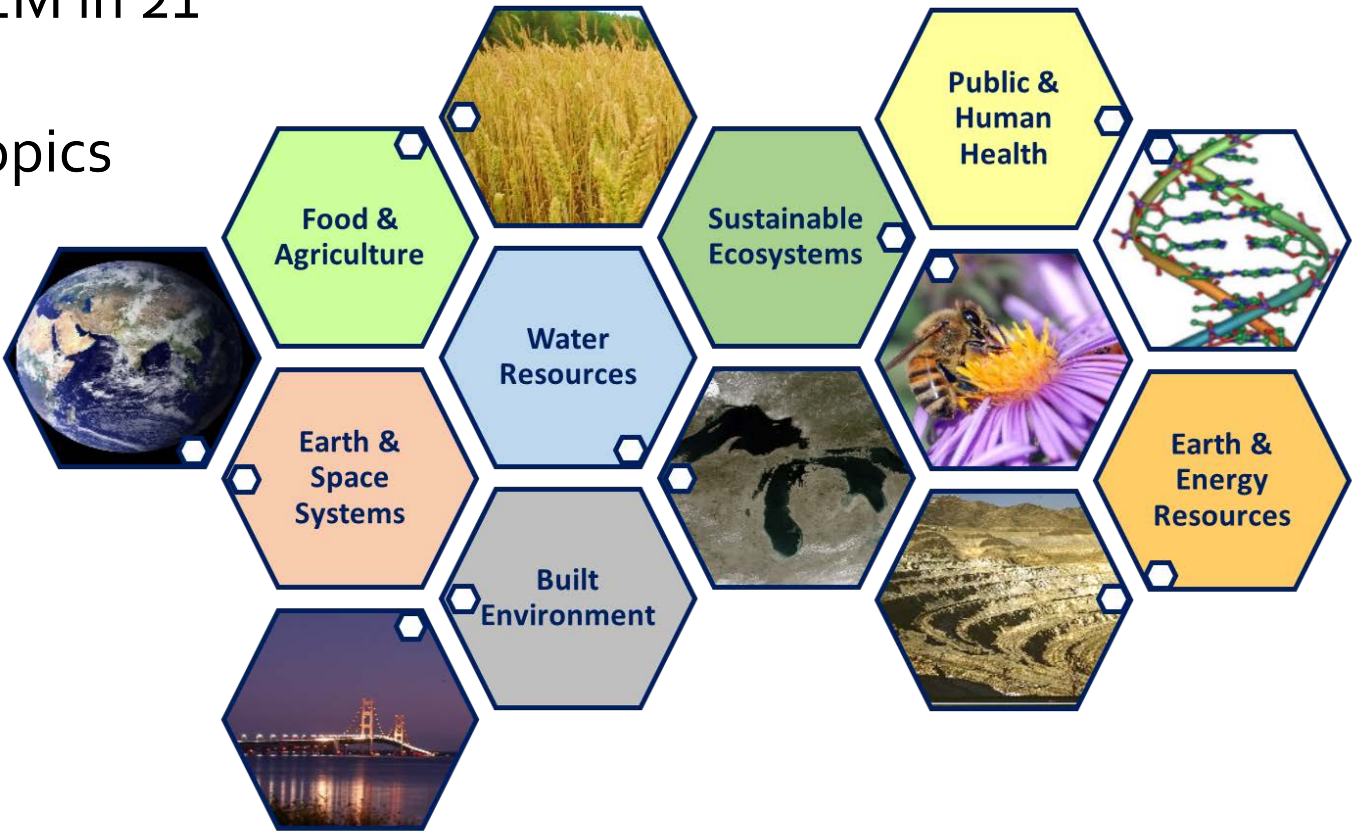


Mi-STAR is…

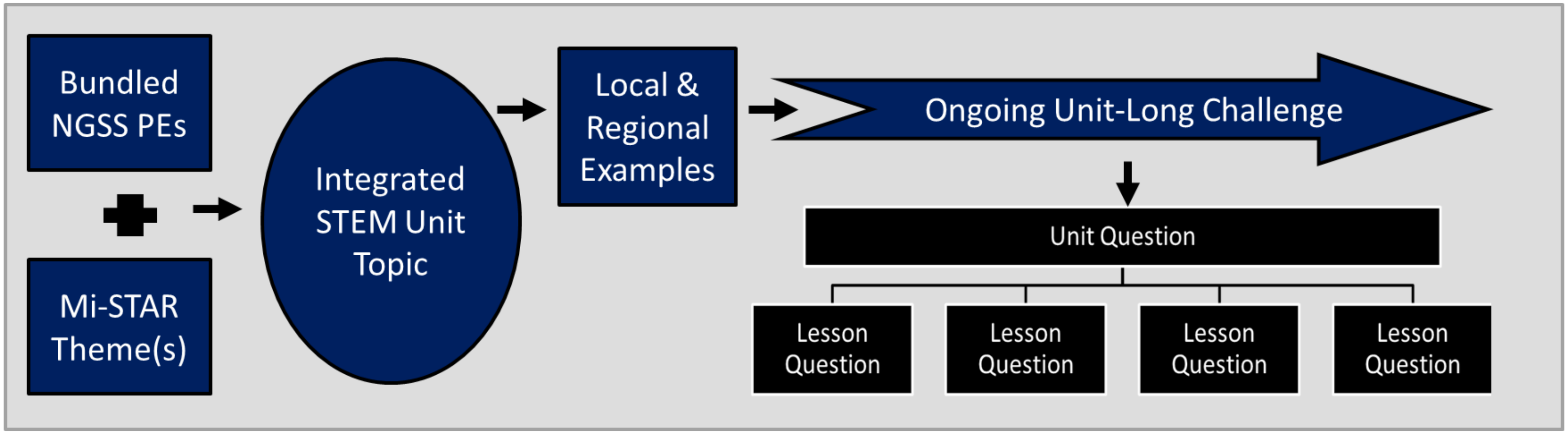
- **Developing new:**
  - Middle school curriculum and assessments
  - Teacher education programs
  - Teacher professional development opportunities

Mi-STAR Themes

- Interdisciplinary
- Apply to STEM in 21st Century
- Drive Unit Topics



Designing a Mi-STAR Unit



Designing an Integrated Curriculum

Building Materials: How We Use Natural Resources

Earth & Energy Resources

Mi-STAR Theme

+

MS-ESS 3-1
Distribution of Natural Resources

MS-ESS 3-4
Impacts of Resource Consumption

MS-PS 1-3
Synthetic Materials & Society

MS-PS 3-3
Thermal Energy Transfer

Bundled NGSS Performance Expectations (PEs)

→

Unit Topic

Earth & Energy Resources

+

MS-ESS 3-1 *Distribution of Natural Resources*

MS-ESS 3-4 *Impacts of Resource Consumption*

MS-PS 1-3 *Synthetic Materials & Society*

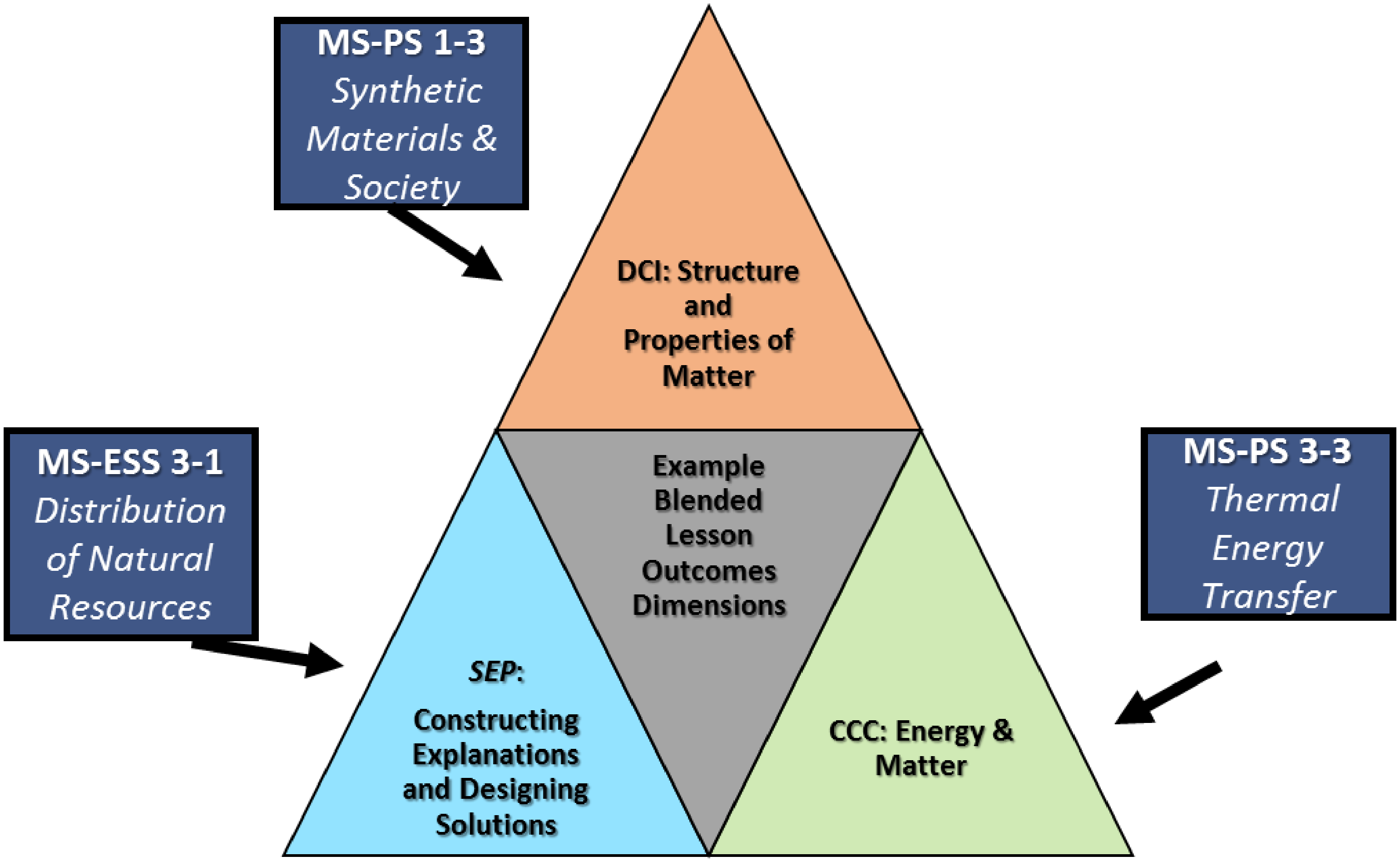
MS-PS 3-3 *Thermal Energy Transfer*

→ Conserving Earth Resources → Michigan Centric

On-Going Unit Challenge

Select the 'best' wall insulation material for a new building in your community.

Lesson Outcomes are Blended & 3D



How do we determine which is the ‘best’ wall insulation?

How are the insulation’s properties unique & useful?

What is insulation made from? How will it be disposed of later?

What effect does the insulation's “Life Cycle” have on Earth Systems?

Select the ‘best’ wall insulation material for a new building in your community.

Lesson 1: Engage in Challenge
Homes from around the world

Lesson 2: Decision Matrix Criteria & Constraints

Lesson 3: Properties of Matter

Lesson 4: Thermal Energy Transfer

Lesson 5: Synthesizing a Synthetic Material

Lesson 6 & 7: Population Growth, Distribution of Natural Resources

Lesson 8 & 9: Material Life Cycle, Impact of Life Cycle on Earth System

Lesson 10: The Final Design

Homes Around the World

Japan

USA

Newfoundland, Canada

Northeast, USA

Challenge: Which is the 'best' wall insulation material for a new building in your community?

Cellulose Insulation

Source: http://archrecord.construction.com/products/productreports/2010/thermal/5_Quiet_Batt_Acoustic_Insulation.jpg

Foam Board Insulation

source: http://hci.frontstepsmedial.netdna-cdn.com/wp-content/uploads/2009/06/extruded-polystyrene-insulation.jpg

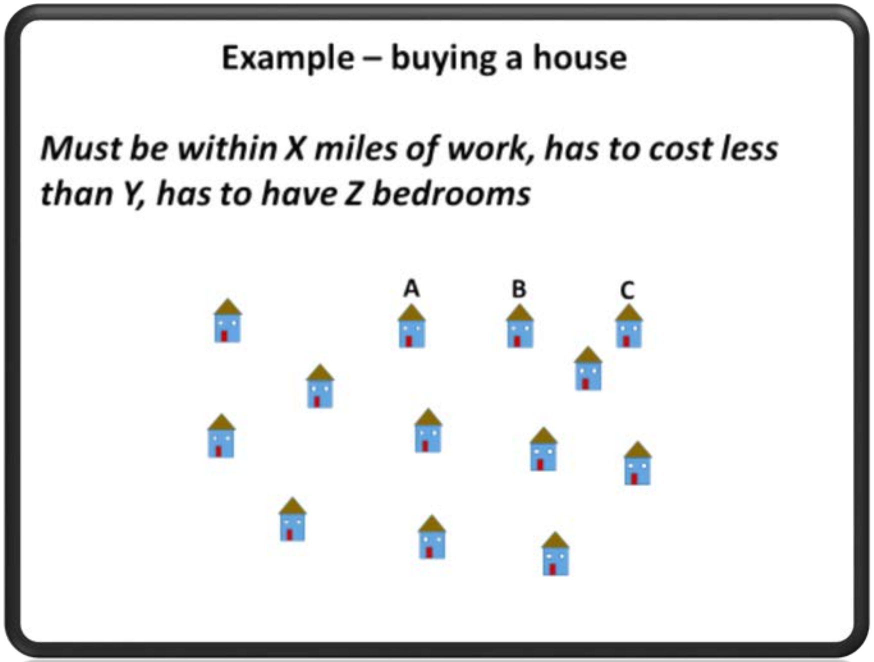
Rock Wool Batt Insulation

Source: http://i.ytimg.com/vi/pkwJwpEqMYo/maxresdefault.jpg

Fiberglass Batt Insulation

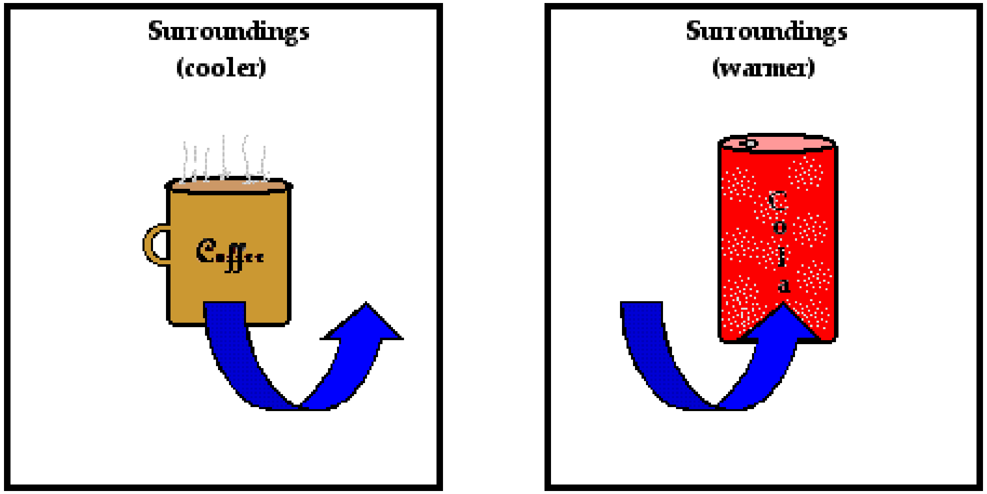
source: http://www.planningtiny.com/wp-content/uploads/2015/03/fiberglass-batt-insulation.jpg

Decision Matrix



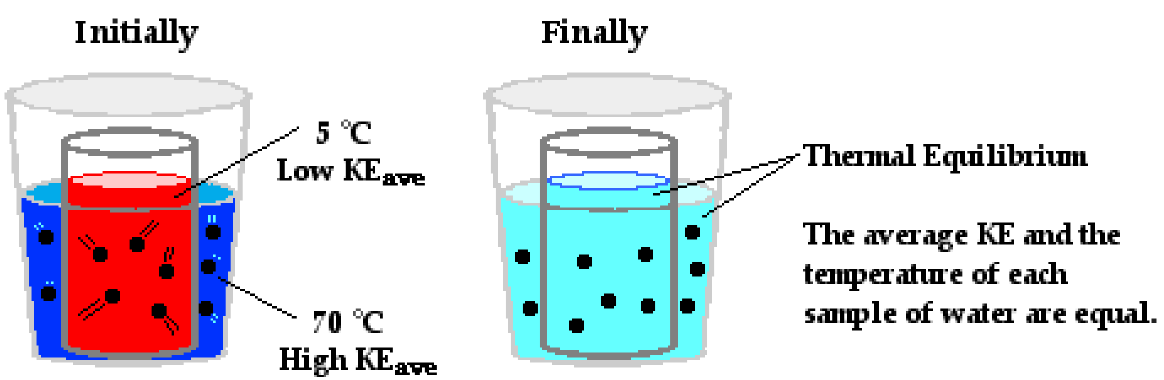
- *Specify the elements of the decision process*
- *ID important assumptions, variables involved*
- *Quantify where possible*
- *Make the decision process systematic, transparent, and understandable…*
- *ID important constraints, criteria, assign criteria values, interpret, and reflect*

Material Properties & Thermal Energy Transfer



Heat is the flow of energy from a high temperature location to a low temperature location.

Source: http://www.physicsclassroom.com/class/thermalP/Lesson-1/What-is-Heat



Rates of Heat Transfer are Affected By:

- Temperature Difference
- Material Properties
  - Thermal Conductivity
  - Reflectivity
  - Thickness

What is *your* climate zone & recommended R-value?

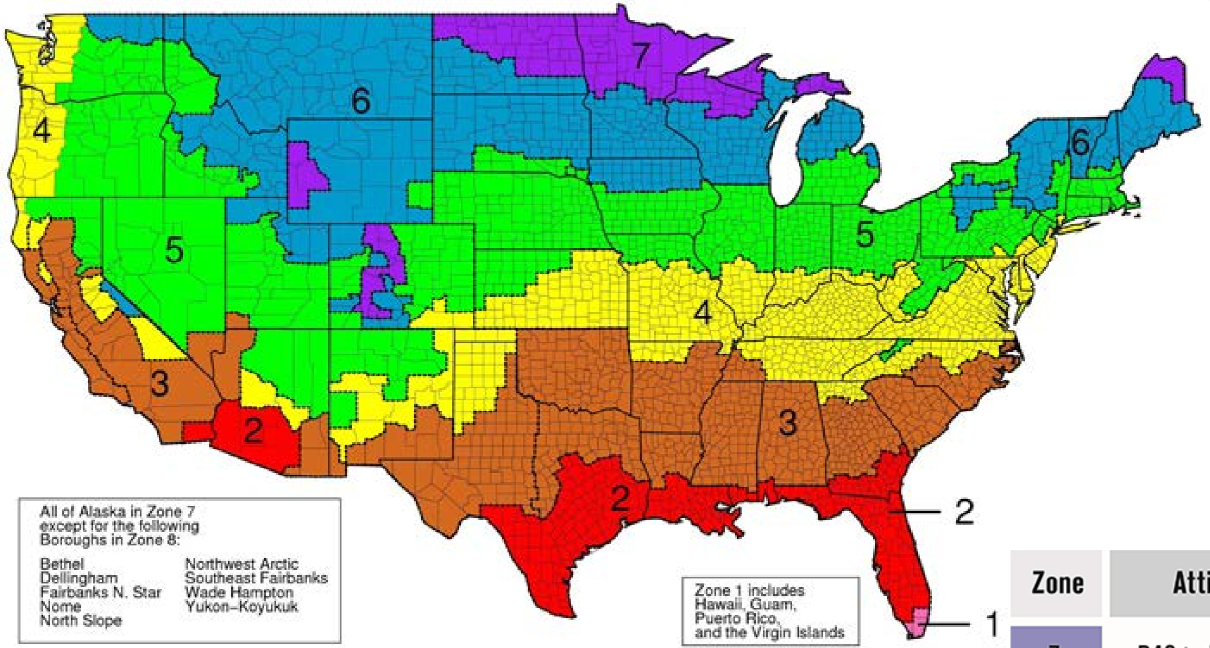


Image sources:
https://www.energystar.gov/ia/home_improvement/home_sealing/images/insulation_map.jpg and
http://www.lowes.com/projects/images/buying-guides/Building-Supplies/insulation-bg-rvalues.jpg

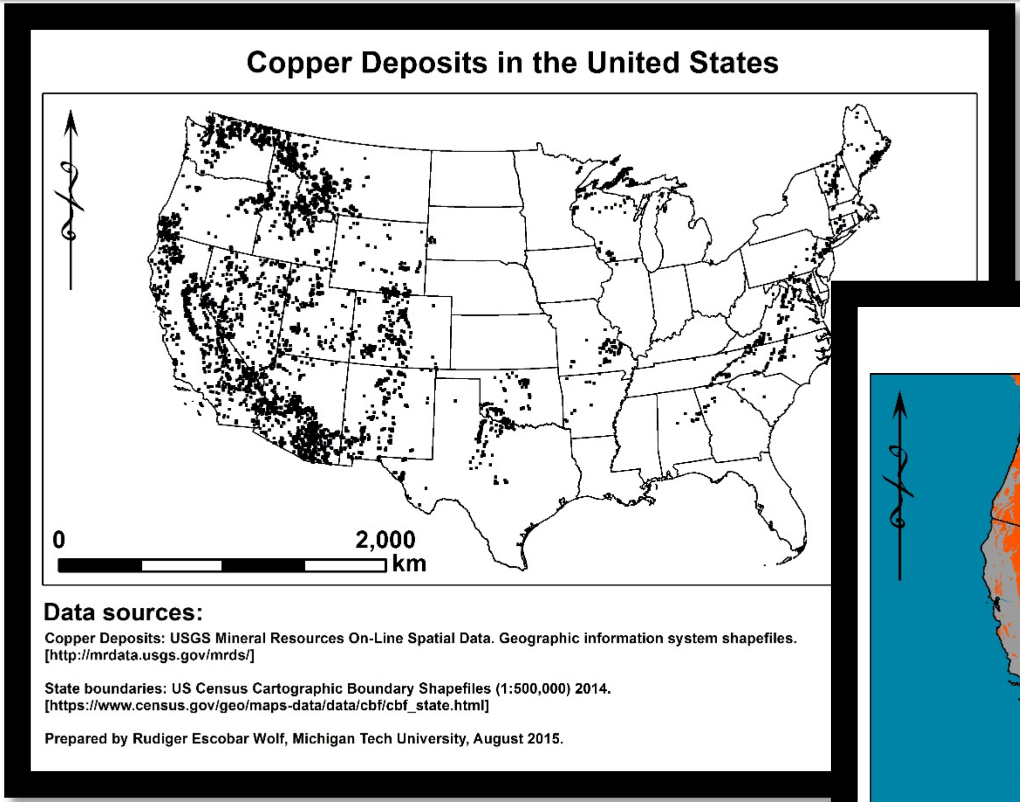
Zone	Attic	2x4 Walls	2x6 Walls	Floors	Crawlspaces
7	R49 to R60	R13 to R15	R19 to R21	R25 - R30	R25 to R30
6	R49 to R60	R13 to R15	R19 to R21	R25 - R30	R25 to R30
5	R49 to R60	R13 to R15	R19 to R21	R25 - R30	R25 to R30
4	R38 to R60	R13 to R15	R19 to R21	R25 - R30	R25 to R30
3	R30 to R60	R13 to R15	R19 to R21	R25	R19 to R25
2	R30 to R60	R13 to R15	R19 to R21	R13	R13 to R19
1	R30 to R49	R13 to R15	R19 to R21	R13	R13

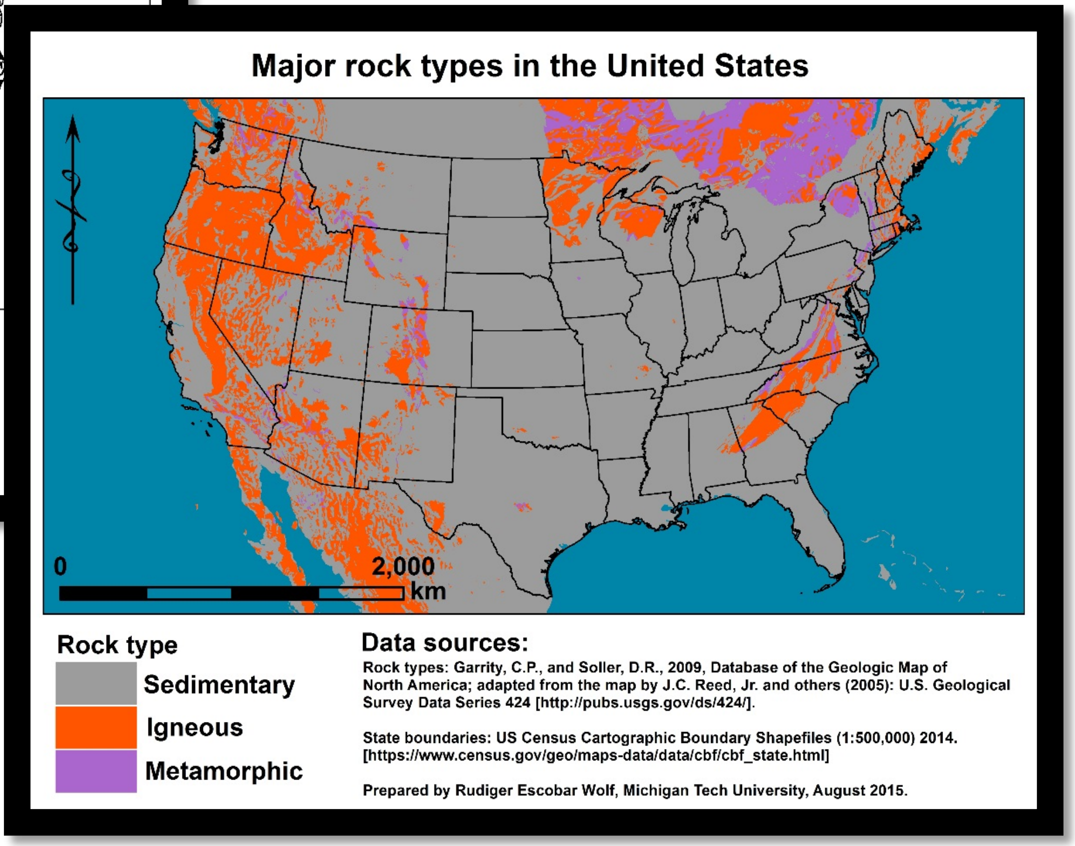
Material R-Value Per Inch

Material	R / inch
Vermiculite	2.3
Cellulose	3.1 - 3.7
Glass Fiber Batts	3.2 - 3.6
Rock Wool Batts	3.5
Polystyrene	3.6 - 5.0
Urethane Foam	5.5 - 6.0

R-Values	11	13	19	22	30
Loose Fill					
Fiberglass	5.0"	5.5"	8.5"	8.5"	13.0"
Rock Wood	3.5"	4.0"	6.0"	6.0"	9.0"
Cellulose	3.0"	3.5"	5.5"	5.5"	8.5"
Vermiculite	5.0"	6.0"	10.5"	10.5"	14.5"
Batts/Blankets					
Fiberglass	3.5"	4.0"	7.0"	7.0"	8.5"
Rock Wool	3.5"	4.0"	7.0"	7.0"	8.5"
Riged Board					
Polystyrene	3.0"	3.5"	3.5"	5.5"	7.5"
Urethane	2.0"	2.0"	2.0"	3.5"	5.0"
Fiberglass	3.0"	3.5"	3.5"	5.5"	7.5"

Uneven Distribution of Natural Resources





Life-Cycle Assessment

Material Life Cycle

www.scienceinthebox.com.de

- **Method of tracking, measuring environmental impacts**
- **Increasing importance in all industries**
  - **- e.g., LEED, U.S. Green Building Council**
- **Reduce environmental impacts of current products / systems**
- **Improve design of new products / systems**

Life-Cycle Assessment

- **All life-cycle stages can have impacts!**

www.scienceinthebox.com.de

Standard Procedures

Defining System is Key!

List of Inputs, Outputs
(build on prior data)

Impact Assessment
(standard methods)

Interpretation
'hot spots' in life cycle?
choose alternatives?

Final Decisions:

Which is the 'best' wall insulation?

DECISION CRITERIA	Objective Weight %	Fiberglass		Cellulose		Foam Board		Rock Wool	
		Rating	Score	Rating	Score	Rating	Score	Rating	Score
Material Properties									
Insulating Value									
Local Availability									
Renewability									
Chemicals & Additives Required									
Energy Consumed									
Recycled Content									
Air Pollution Emitted									
Total	100%								

Objective Weight% x Rating = Score

Thank you!

Mi-STAR: A model for integrated science reform

MichiganTech

For further information visit the Mi-STAR website at http://mi-star.mtu.edu

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Mi-STAR
Michigan Science Teaching and Assessment Reform

Unit 7.3 Overview

Building Materials: How we use our Natural Resources

This is the third unit of the 7th grade Mi-STAR curriculum. It primarily uses the theme Energy and Earth Resources as it explores thermal energy transfer, nonrenewable resources, and human impacts on Earth systems. There are 10 lessons within this interdisciplinary unit. Throughout this unit, students will seek to answer the unit question:

How can resource availability affect our lifestyles, and how can our lifestyles affect resource availability?

Next Generation Science Standards

Unit 7.3 has four primary NGSS Performance Expectations associated with its lessons. Within these Performance Expectations are three of the eight Science and Engineering Practices, three of the seven Cross-Cutting Concepts, and eight Disciplinary Core Ideas; all of which are presented here.

MS-ESS3-1: Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. [Clarification Statement: Emphasis is on how these resources are limited and typically non-renewable, and how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (locations of the burial of organic marine sediments and subsequent geologic traps), metal ores (locations of past volcanic and hydrothermal activity associated with subduction zones), and soil (locations of active weathering and/or deposition of rock).

MS-PS1-3: Gather and make sense of information to describe that synthetic materials come from natural resources and impact society. [Clarification Statement: Emphasis is on natural resources that undergo a chemical process to form the synthetic material. Examples of new materials could include new medicine, foods, and alternative fuels.] [*Assessment Boundary: Assessment is limited to qualitative information.*]

MS-PS3-3: Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.* [Clarification Statement: Examples of devices could include an insulated box, a solar cooker, and a Styrofoam cup.] [*Assessment Boundary: Assessment does not include calculating the total amount of thermal energy transferred.*]

MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems. [Clarification Statement: Examples of evidence include grade-appropriate databases on human populations and the rates of consumption of food and natural resources (such as freshwater, mineral, and energy). Examples of impacts can include changes to the appearance, composition, and structure of Earth's systems as well as the rates at which they change. The consequences of increases in human populations and consumption of natural resources are described by science, but science does not make the decisions for the actions society takes.

Lesson 1: Home Designs Around the World

Lesson Overview: The use of building materials and methods for the construction of homes has evolved over time and varies among different regions of the world. For example, when humans first settled, homes were built by the materials available on hand, including grass, wood, stone, and dry clay (brick). The search for more durable materials to build long-lasting dwellings has led to a variety of other materials to be used, including concrete and steel. Today, in certain parts of the world, synthetic materials are being used, such as composite siding and fiber cement board. The selection of materials for home construction depends on a number of factors, including the lifestyle of the occupant, material properties, resource availability, local climate, financial constraints, and cultural values. One consideration that is increasingly prevalent in the selection of materials and home design is energy efficiency (minimizing the transfer of thermal energy lost from or gained by the home). Scientific research and technology has helped create more energy-efficient homes through the use of synthetic materials. However, Earth's systems can be impacted by the extraction of raw materials, the production of synthetic materials, and the disposal of materials at the end of their useful life. In this lesson, students examine a range of home construction designs and materials from around the world and over time. They consider the reasons why certain materials are chosen over others when building homes. Then, students examine the relationship between a home's design and the conservation of resources by comparing a straw bale house to their own homes (or a typical Michigan house). At the lesson's conclusion, students are introduced to the Ongoing Unit Challenge scenario in which they begin to evaluate the best wall insulation material for a new community center.

Introduction to the Ongoing Unit Challenge: Introduction to the Ongoing Unit Challenge: Your local mayor is competing for an environmental sustainability award that, if won, could bring much-needed tourist dollars, federal grant money, and good publicity for your community. The city council has decided to build a community center that will provide new programs for the local population. In order to improve the mayor's possibility of winning, (s)he has commissioned several engineering firms (small student groups) to test individual insulation materials for the walls of the building that balance energy efficiency with the environmental impact of the specific insulation material. Each group (engineering firm) will use knowledge based on the upcoming lessons of the unit to measure certain characteristics of their material to decide whether it might be a good one to use. At the end of the unit, all groups will come together to share their results and decide which material would be best to use for the community building and give the project the best chance of winning the environmental sustainability award.

Lesson Questions

- *Why do the designs and materials used in home construction vary among different communities and over time?*
- *How are the designs and materials selected for home construction related to resource conservation?*

Constructing Explanations and Designing Solutions *- Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system.*(MS-PS3-3)		**Connections to Engineering, Technology, and Applications of Science** **Influence of Science, Engineering, and Technology on Society and the Natural World** *- The uses of technologies and any limitation on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.* (MS-PS1-3) **Influence of Science, Engineering, and Technology on Society and the Natural World** *All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.* (MS-ESS3-1)

Lesson 2: Decision Criteria and Constraints

Lesson Overview: The design of a solution to an engineering problem must consider two factors. The first are the requirements for the design. These are referred to as the criteria. The second are the design restrictions, or limits, that are imposed externally. These are referred to as the constraints. For example, a criterion for a building design would be the properties of the building materials. A constraint for the building design would be the availability of resources. In this lesson, students begin to think about the criteria that will guide them in their selection of building materials to be used in the unit-long challenge. These will include insulating value, local availability, renewability, and impact on the environment from the use, extraction, and disposal of their material. The Engage and Explore will introduce students to the concept of a Decision Matrix and how this tool can be used in engineering and construction projects. Groups will be given a wall insulation material for the ongoing unit challenge, and the class will set up a decision matrix by choosing a weight for each of the criteria mentioned above.

Introduction to the Ongoing Unit Challenge: Students are introduced to both their ongoing unit challenge insulation materials and the Decision Matrix engineering tool to help them make decisions based on their material's properties throughout the challenge.

Lesson Questions

➔ *How can we determine which solution will be the most successful in solving an engineering problem?*

Constructing Explanations and Designing Solutions *- Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system.* (MS-PS3-3)	**ETS1.A: Defining and Delimiting an Engineering Problem** *The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.*(PS3-3 secondary) **ETS1.B: Developing Possible Solutions** *A solution needs to be tested, and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem.* (PS3-3 secondary)	**Connections to Engineering, Technology, and Applications of Science** **Influence of Science, Engineering, and Technology on Society and the Natural World** *- The use of technology are driven by societal needs and difference in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.* (MS-PS1-3)

Lesson 3: Properties of Natural and Processed Materials

Lesson Overview: Students will identify natural and synthetic materials using known chemical and physical properties of matter. The natural and synthetic materials that students examine are ones used by people on a daily basis because their properties are useful. Synthetic materials are derived from natural resources and designed and developed for their useful properties. People choose natural and synthetic products based on the needs of the situation.

Introduction to the Ongoing Unit Challenge: Students observe the structure and properties of their insulation materials that enhance their function to meet humans' needs. Students obtain information about wall insulation from websites then weigh the "Material Properties" criteria in the Decision Matrix.

Lesson Questions

➔ *What are the properties of materials that make them useful to humans?*

Obtaining, Evaluating, and Communicating Information: *- Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or not supported by evidence.* (PE 1-3)	**PS1.A: Structure and Properties of Matter** *Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.* (PS1-3)	**Structure and Function** Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (PS1-3) **Connections to Engineering, Technology and Applications of Science** **Interdependence of Science, Engineering, and Technology** *- Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems.* (PS1-3)

Mi-STAR Michigan Science Teaching and Assessment Reform

Lesson 4: Thermal Energy in Action

Lesson Overview: Students test the rates of heat transfer through cups made of a range of different materials. They analyze temperature measurements to determine the variables which affect the rate of thermal energy transfer. Students will observe that some materials are better at conducting (or insulating) thermal energy than others and that a material's properties can either maximize or minimize thermal energy transfer. This sets the stage for testing the insulating value of the materials selected for the ongoing unit challenge. Results will be recorded on each group's unit-long decision matrix.

Introduction to the Ongoing Unit Challenge: Students learn about thermal properties of materials and that products can either enhance (conduct) or minimize (insulate) thermal heat transfer. Activities in the Elaborate guide students to consider their ongoing unit challenge insulation material and calculate the R-value as an input into the Decision Matrix.

Lesson Questions

- ➔ *How can we slow the rate that heat is transferred?*

Constructing Explanations and Designing Solutions *- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.* (MS-ESS3-1)	**PS3.A: Definitions of Energy** *-Temperature is a measure of the average kinetic energy of particles of matter. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present*. (MS-PS3-3) **PS3.B: Conservation of Energy and Energy Transfer** *- Energy is spontaneously transferred out of hotter regions or objects and into colder ones.* (MS-PS 3-3)	**Energy and Matter** - The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS3-3)

Lesson 5: Synthesizing a Synthetic

Lesson Overview: Students look at how natural resources are changed to create synthetic materials which have particular properties that make them useful for specific needs (concrete, etc.). They discover that synthetic materials originate from raw materials that are natural resources, both renewable and nonrenewable, that undergo chemical changes to enhance designated properties.

Introduction to the Ongoing Unit Challenge: Students read provided sources to identify the inputs and processes required to create their insulation material for the ongoing unit challenge. Students evaluate whether the materials are naturally occurring or synthetic. Students rate the criteria in their Decision Matrix.

Lesson Questions

- ➔ *Where do synthetic materials come from?*
- ➔ *How is matter changed to create the materials we use?*

Obtaining, Evaluating, and Communicating Information	PS1.B: Chemical Reactions	Structure and Function
Obtaining, evaluating, and communicating information in 6–8 builds on K–5 and progresses to evaluating the merit and validity of ideas and methods. *-Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or now supported by evidence.* (PS1-3)	*Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (PS1-3)* **PS1.A: Structure and Properties of Matter** *Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (PS1-3)*	*- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (PS1-3)* **Energy and Matter** *- The transfer of energy can be tracked as energy flows through a designed or natural system. (PS3-3)*

Lesson 6: Different Places, Different Resources

Lesson Overview: In this lesson, students continue to further investigate the wall insulation material for the unit-long challenge by answering the question, "Why are natural resources found in certain locations and not others?" Examining how past and current geological processes creates an uneven distribution of natural resources allows for an investigation of how non-renewable resources are limited by the rate and distribution of the geologic processes that create them. Resource distribution changes when humans begin extracting and consuming resources. Resource availability and distribution also changes due to the timescales it takes to regenerate a resource. The class uses a very general example (salt) to begin thinking about how it forms and how large deposits are distributed and what geological factors played a role in its formation. Students will use models (maps) to identify patterns in resource distribution and generate an understanding that geological processes dictate natural resource distribution. Students will then be provided information and maps regarding the distribution of their wall insulation raw material and make interpretations about its local availability and renewability, which will be incorporated into the Ongoing-Unit-Challenge Decision Matrix.

Introduction to the Ongoing Unit Challenge: Students use data gathered during the Elaborate to provide values for "Local Availability" and "Renewability" in their Decision Matrix.

Lesson Questions

- ➔ *Why are natural resources found in certain locations and not others?*
- ➔ *Why is natural resource distribution and availability important to society?*

Engaging in Argument from Evidence *- Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.* (ESS3-4) **Constructing Explanations and Designing Solutions** *- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future*.(MS-ESS3-1)	**ESS3.A: Natural Resources** *Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.* (MS-ESS3-1)	**Connections to Engineering, Technology, and Applications of Science** **Influence of Science, Engineering, and Technology on Society and the Natural World** *- The use of technology are driven by societal needs and difference in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.* (MS-PS1-3)

Lesson 7: Human Population and Resource Consumption

Lesson Overview: Human population growth and changing lifestyles are increasing human consumption of natural resources. This consumption, in turn, has an impact on the Earth's systems through the use and disposal of materials. In this lesson, students examine the relationship between population growth, consumption of resources, as well as the impacts of resource use and disposal on Earth's systems. Students also explore how engineering solutions can minimize some of these negative impacts to Earth systems.

Introduction to the Ongoing Unit Challenge: Students reflect on how population growth increases demand on natural resources. Students investigate whether depletion of nonrenewable resources affect the availability of their insulation material. Criteria of renewability and local availability are revisited/reweighed in the Decision Matrix.

Lesson Questions

- ➔ *How is human population growth connected to changes in resource consumption?*
- ➔ *What role can science and technology play in natural resource conservation?*

Engaging in Argument from Evidence *- Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.* (ESS3-4)	**ESS3.A: Natural Resources** *Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.* (MS-ESS3-1) **ESS3.C: Human impact on Earth's systems** *Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.*(MS-ESS3-4)	**Connections to Engineering, Technology, and Applications of Science** **Influence of Science, Engineering, and Technology on Society and the Natural World** *- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.* (MS-PS1-3)

Lesson 8: Life Cycles of Products

Lesson Overview: Societies require tremendous amounts of natural resources to meet the needs of growing populations; more than any point in the past. Every material we buy at the store requires natural resources or other inputs at every stage in its life cycle. In this lesson, students consider the life cycle of natural resources. They think about how certain resources are used to create the products they use. They examine how these products are made from raw materials that are obtained from the natural environment. Then, they look at how those materials are processed and manufactured to create the goods needed by modern society. They also contemplate what happens to products after they are no longer useful. Students discover that each material or product we use has a life cycle and that each stage of the product's life cycle has inputs and outputs. The transfer of energy (and matter) can be tracked as energy (or matter) flows through a designed or natural system. The Life Cycle Assessment is an engineering tool to quantify the economics, human impact, energy required, materials, environmental impact, and wastes produced at each stage of a product's life cycle from cradle (design) to grave (disposal).

Introduction to the Ongoing Unit Challenge: Groups will now consider the Lifecycle of their insulation material. Students review written information on the life cycle of the material and compile the information below. Students revisit the Decision Matrix to rate the value for "recycled content, energy used, chemical inputs and air pollution." The students will use information from this lesson and others to create a presentation for the whole class in the final lesson.

Lesson Questions

- ➔ *What are the different stages in the life cycles of the products that we use?*
- ➔ *How can a life cycle assessment be helpful for conserving natural resources?*

Obtaining, Evaluating, and Communicating Information

- Gather, read, and synthesize information from multiple appropriate sources and assess the credibility, accuracy, and possible bias of each publication and methods used, and describe how they are supported or now supported by evidence. (MS-PS1-3)

Constructing Explanations and Designing Solutions

- Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. (MS-PS3-3)

ESS3.C: Human Impacts on Earth Systems

Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (MS-ESS3-4)

ETS1.B: Developing Possible Solutions

A solution needs to be tested, and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. (secondary) (MS-PS-3-3)

Energy and Matter

- The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS3-3)

Influence of Science, Engineering, and Technology on Society and the Natural World

-All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ESS3-1)

-Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. (MS-PS3-1)

Energy and Matter

- Matter is conserved because atoms are conserved in physical and chemical processes. (secondary)

Lesson 9: LCAs and Impacts on Earth Systems

Lesson Overview: Human population growth and changing lifestyles are increasing human consumption of natural resources. This consumption, in turn, has an impact on Earth systems: during extraction of raw materials, production of refined materials, use of materials, and in disposal of materials. In this lesson, students will examine this relationships between population growth and consumption as well as consumption and changes to Earth systems. Students will also explore how engineering solutions can minimize some of these negative impacts to Earth systems.

Introduction to the Ongoing Unit Challenge: Students will review a case study describing one stage of their material's LCA and the impact on Earth Systems. Student will recommend/design a solution to reduce the negative effects of the impact based on scientific ideas. The students then compile this information to be shared as part of their presentation during the final lesson.

Lesson Questions

➔ *How does the extraction and use of natural resources impact Earth's systems?*

Engaging in Argument from Evidence

- Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (ESS3-4)

Constructing Explanations and Designing Solutions

- Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. (MS-PS3-3)

ESS3.C: Human impact on Earth's systems

Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth Systems unless the activities and technologies involved are engineered otherwise. (MS-ESS3-4)

ESS3.A: Natural Resources

Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes.(MS-ESS3-1)

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Connections to Engineering, Technology, and Applications of Science

Science Addresses Questions About the Natural and Material World

-Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

Influence of Science, Engineering, and Technology on Society and the Natural World

- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.

Lesson 10: Final Design!

Lesson Overview: The final evaluate lesson encompasses a performance based opportunity to tie concepts from all previous lessons together in a culminating activity. Student groups compile the information they have collected and present the results from their decision matrix based on their specific material into a Class Decision Matrix. A larger, class-wide discussion occurs that allows the class to weigh each material against the others. Students debate the information from their results, and the students justify the reasoning for their assigned weighting/ranking. Ideally, consensus can be achieved through class discussion to make a final decision on the best insulation material for the energy efficient community building scenario that also maximizes resource conservation. Depending on their weighting of criteria, students may do this through thermal efficiency, use of local/regional materials, and/or use of renewable materials. Ideally, students will consider and address all three factors in their final design decision.

Introduction to the Ongoing Unit Challenge: Groups will present the information on their insulation material that they have compiled throughout the unit to present to the rest of the class. During this presentation the rating and scores will be filled in on the Class Decision Matrix. Based on these results the students will consider the best design for wall insulation in the community building scenario, and provide a recommendation. Each individual student will write a letter to the town mayor to describe their final decision using evidence based reasoning to justify their recommendation.

Lesson Questions

- ➔ *Which wall insulation material will maximize conservation of natural resources and thermal energy?*
- ➔ *How confident are we in our decision making process?*

Constructing Explanations and Designing Solutions

- Apply scientific ideas or principles to design, construct, and test a design of an object, tool, process or system. (MS-ESS3-1)

ETS1.A: Defining and Delimiting an Engineering Problem

The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that is likely to limit possible solutions.(MS-PS3-3 secondary)

ETS1.B: Developing Possible Solutions

A solution needs to be tested, and then modified on the basis of the test results in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet criteria and constraints of a problem. (MS-PS3-3 secondary)

Energy and Matter

- The transfer of energy can be tracked as energy flows through a designed or natural system.

Connections to Engineering, Technology, and Applications of Science

Science Addresses Questions About the Natural and Material World

-Scientific knowledge can describe the consequences of actions but does not necessarily prescribe the decisions that society takes.

Searching for Earth's Twin: NASA's Kepler Mission--1,000 Exoplanets and Counting – Edna DeVore (SETI Institute) and Alan Gould (Lawrence Hall of Science)

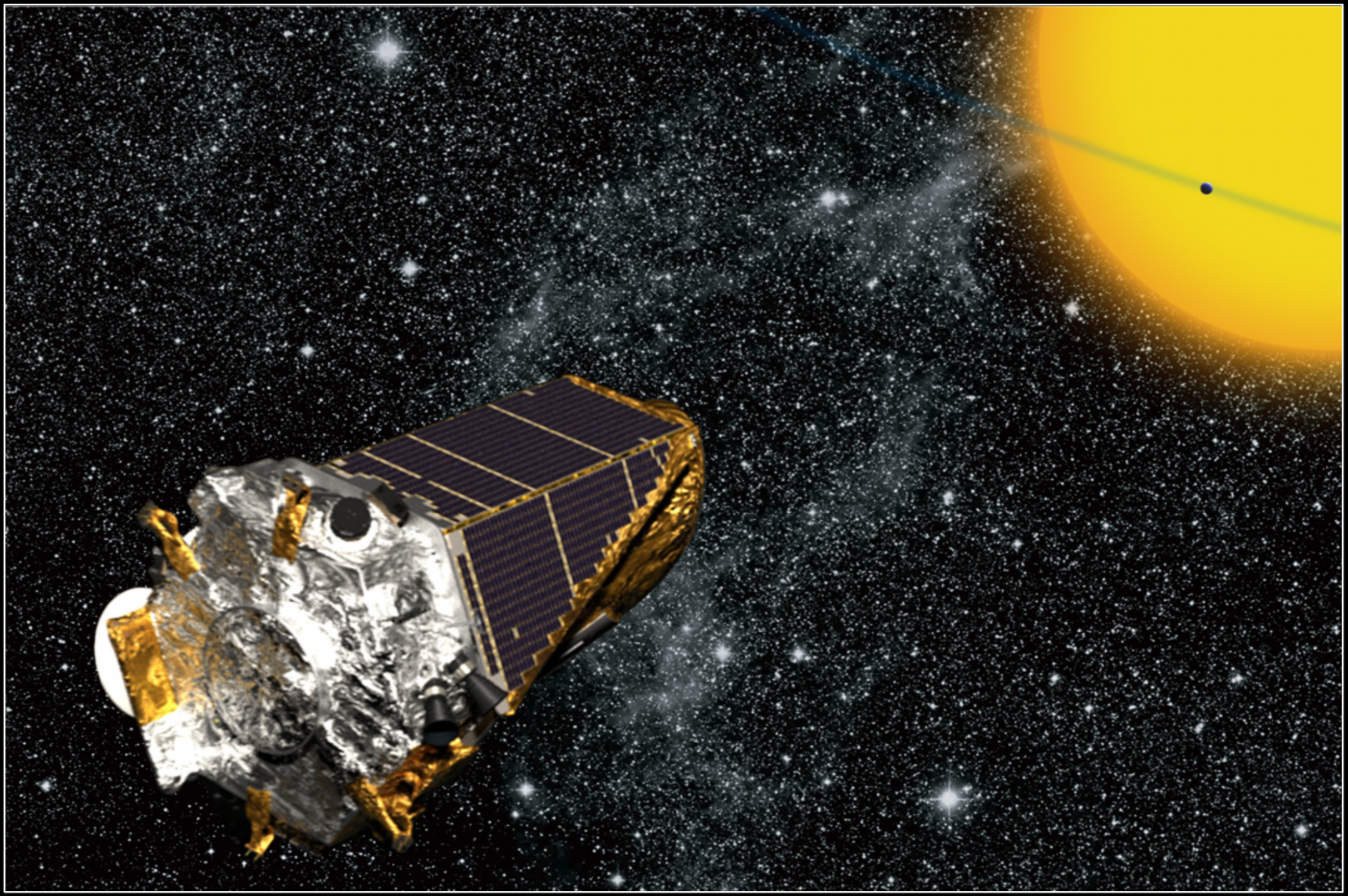
A Search for Habitable Planets

Transit Tracks:
Finding Extrasolar Planets

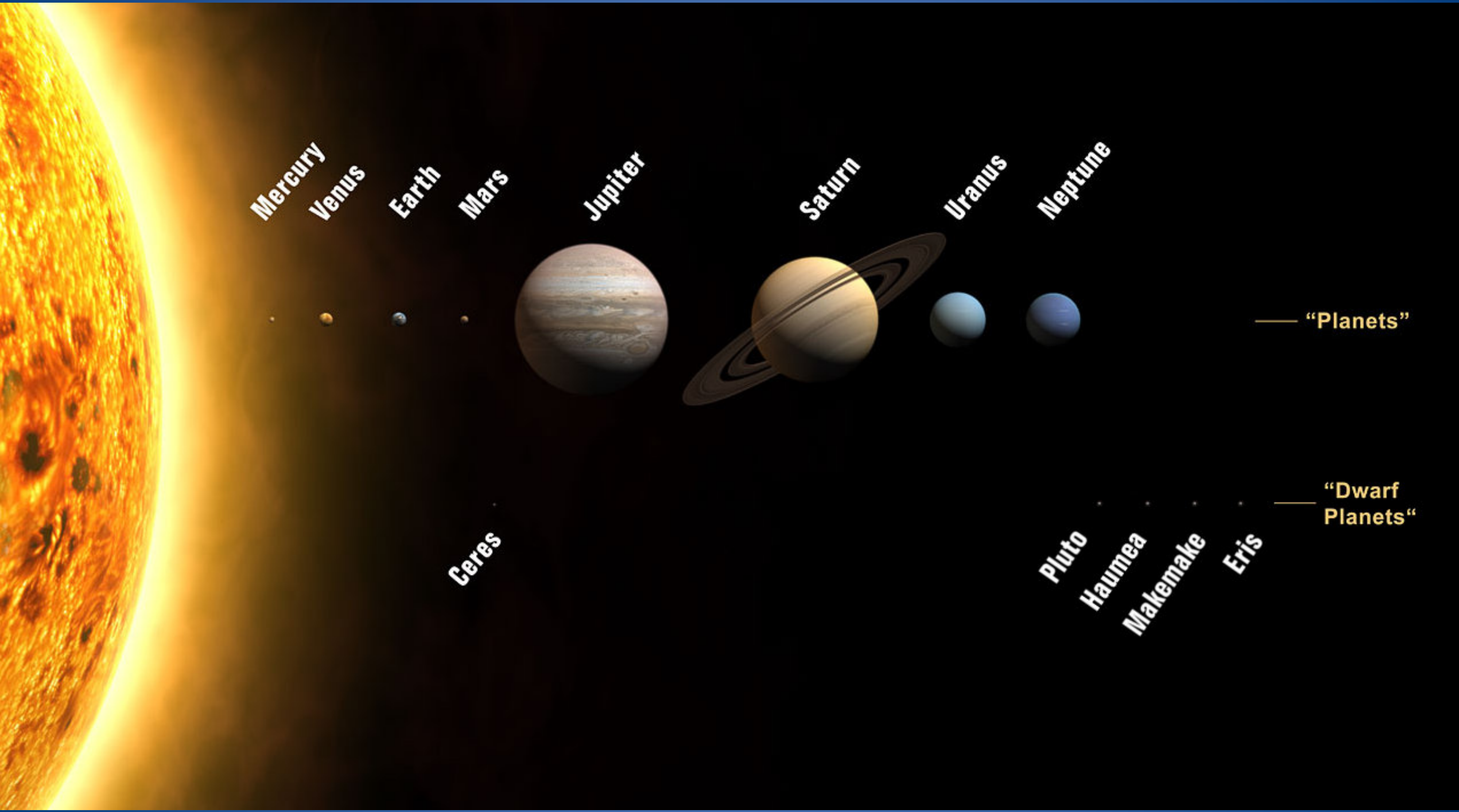
a science & math activity

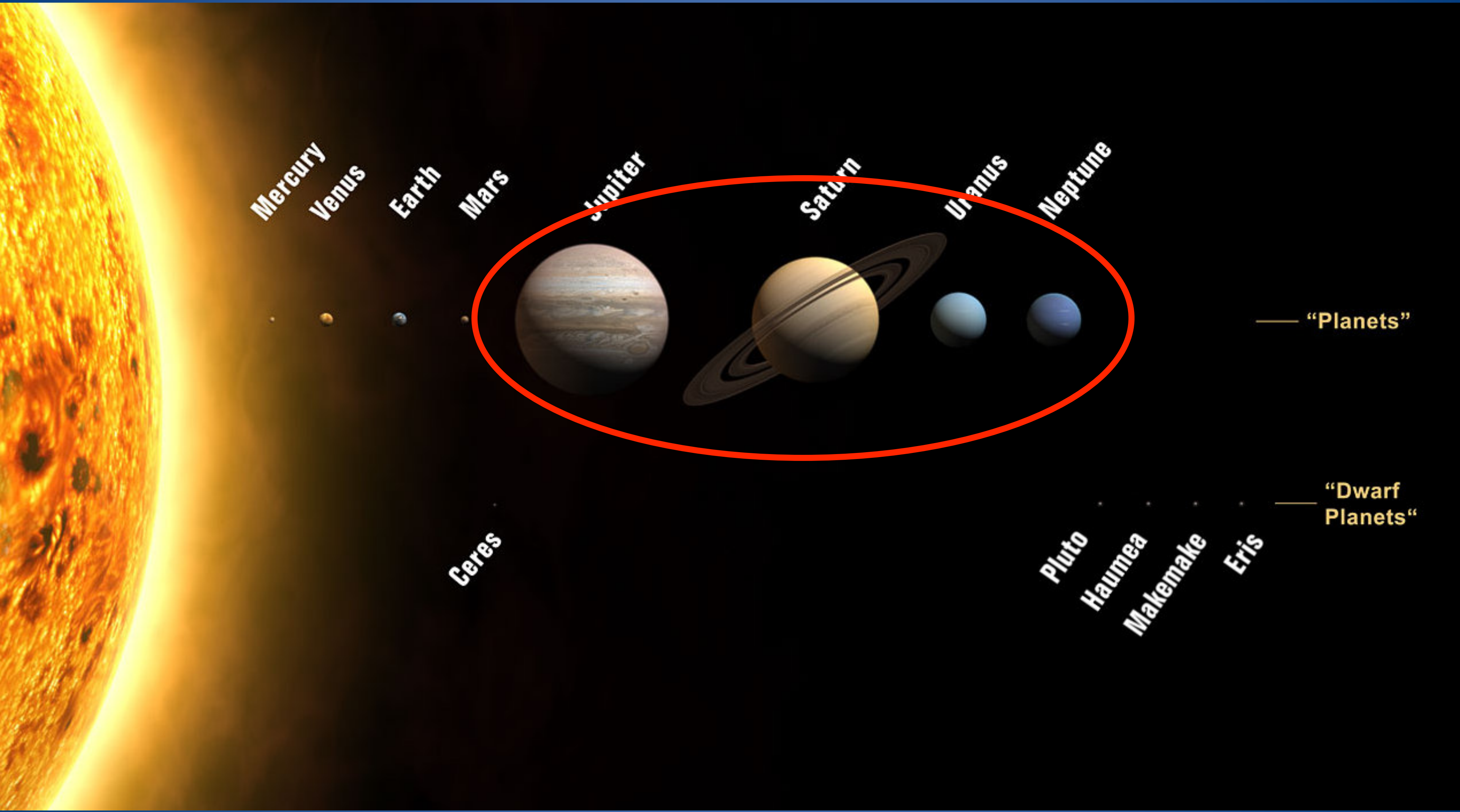
Kepler Mission Goal

Kepler seeks evidence of Earth-size planets in the habitable zone of Sun-like stars.

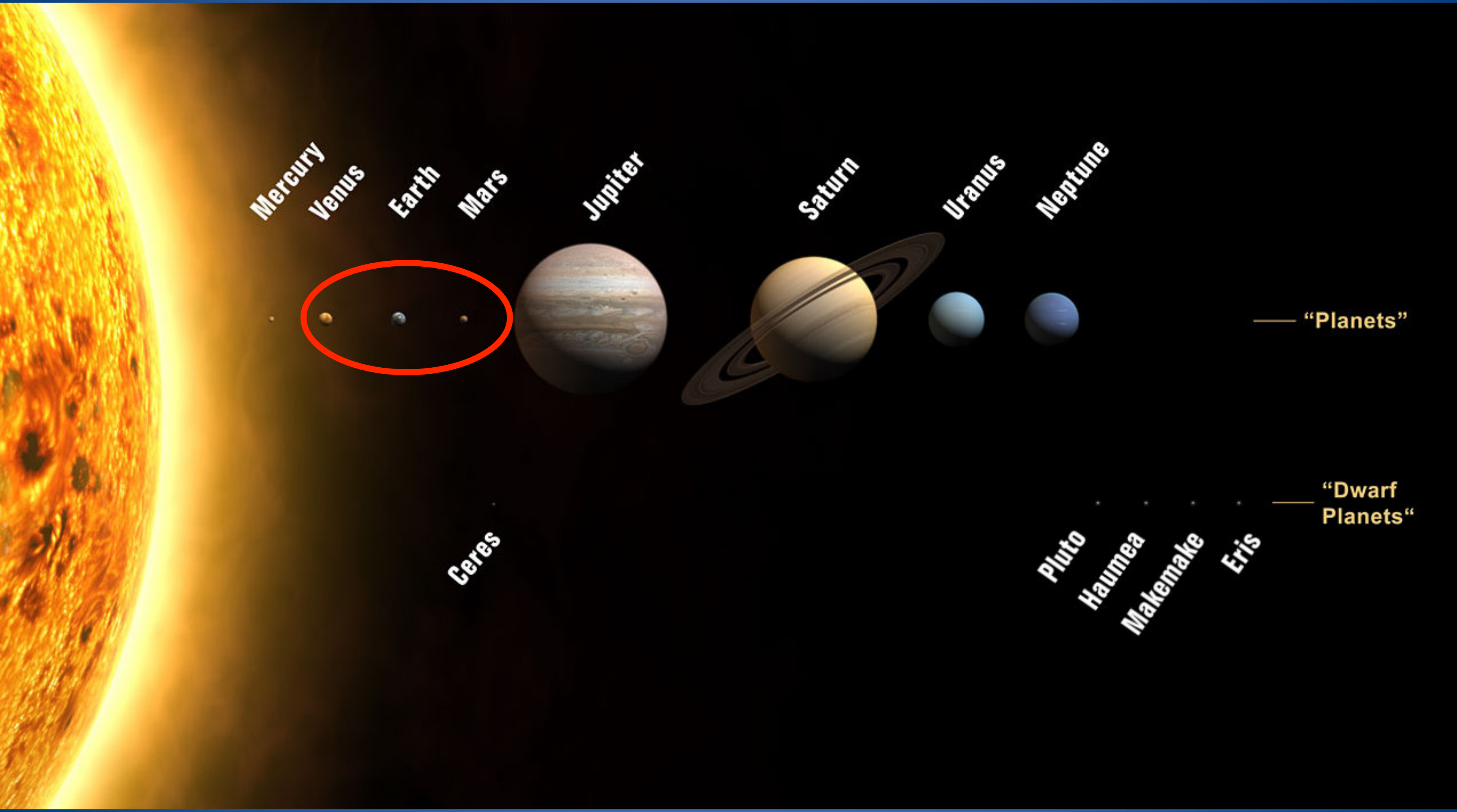


A Search for Habitable Planets



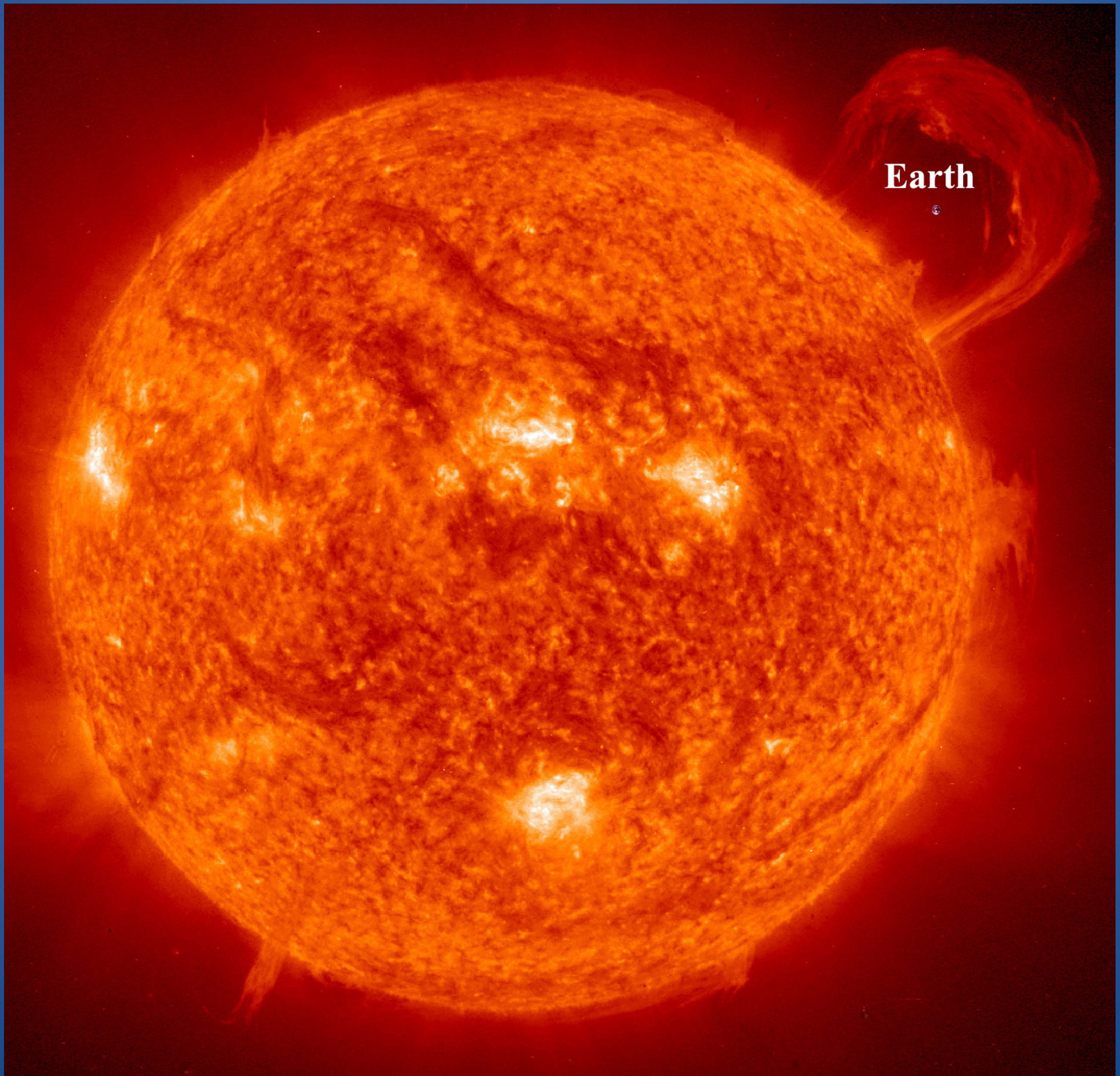

Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune
"Planets"
Ceres
Pluto
Haumea
Makemake
Eris
"Dwarf Planets"

A Search for Habitable Planets



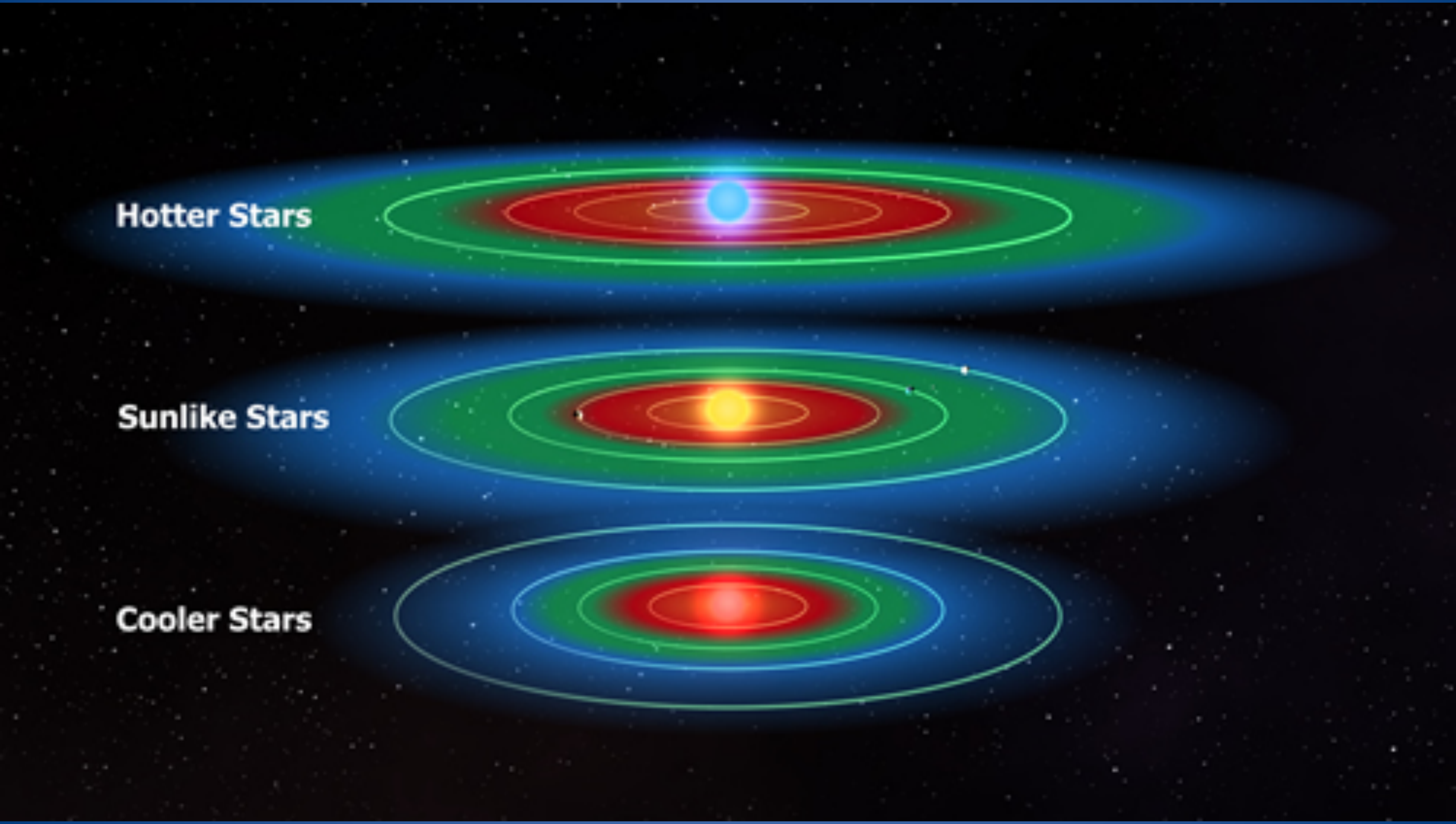
What is Earth-size & Sun-size?

Kepler
A Search for Habitable Planets



What is the habitable zone?

A Search for Habitable Planets



What is a “transit”?

A Search for Habitable Planets

"transit"

A Search for Habitable Planets

"transit"

A Search for Habitable Planets

What's this?

A Search for Habitable Planets

A transit of Venus across the Sun takes place when the planet Venus passes directly between the Sun and Earth, so that Venus blocks a small spot of the Sun's disk. Since the Sun is over 100 times larger in diameter than Venus, the spot is very small indeed.

Account of Jeremiah Horrock's observations of the transit of Venus

A Search for Habitable Planets

An Englishman, Jeremiah Horrocks, made the first European observation of a transit of Venus from his home in Much Hoole, England, in the winter of 1639. Horrocks had read about Johannes Kepler who predicted transits in 1631 and 1761, and a near miss in 1639 when Venus would pass very close to the Sun, but not actually in front of it. Horrocks made corrections to Kepler's calculation for the orbit of Venus and predicted that 1639 would not be a near miss, but an actual transit. He was uncertain of the exact time, but calculated that the transit would begin about 3:00 pm. He focused the image of the Sun through a simple telescope onto a card, where the image could be safely observed.

After watching for most of the day with clouds obscuring the Sun often, he was lucky to see the transit as clouds cleared at about 3:15 pm, just half an hour before sunset. The observations allowed him to make a well-informed estimate as to the size of Venus, but more importantly, using geometry, to calculate the distance between the Earth and the Sun which had not been known accurately at that time. He was the first of many people who used transit observations to try to determine the distance from the Sun to the Earth.

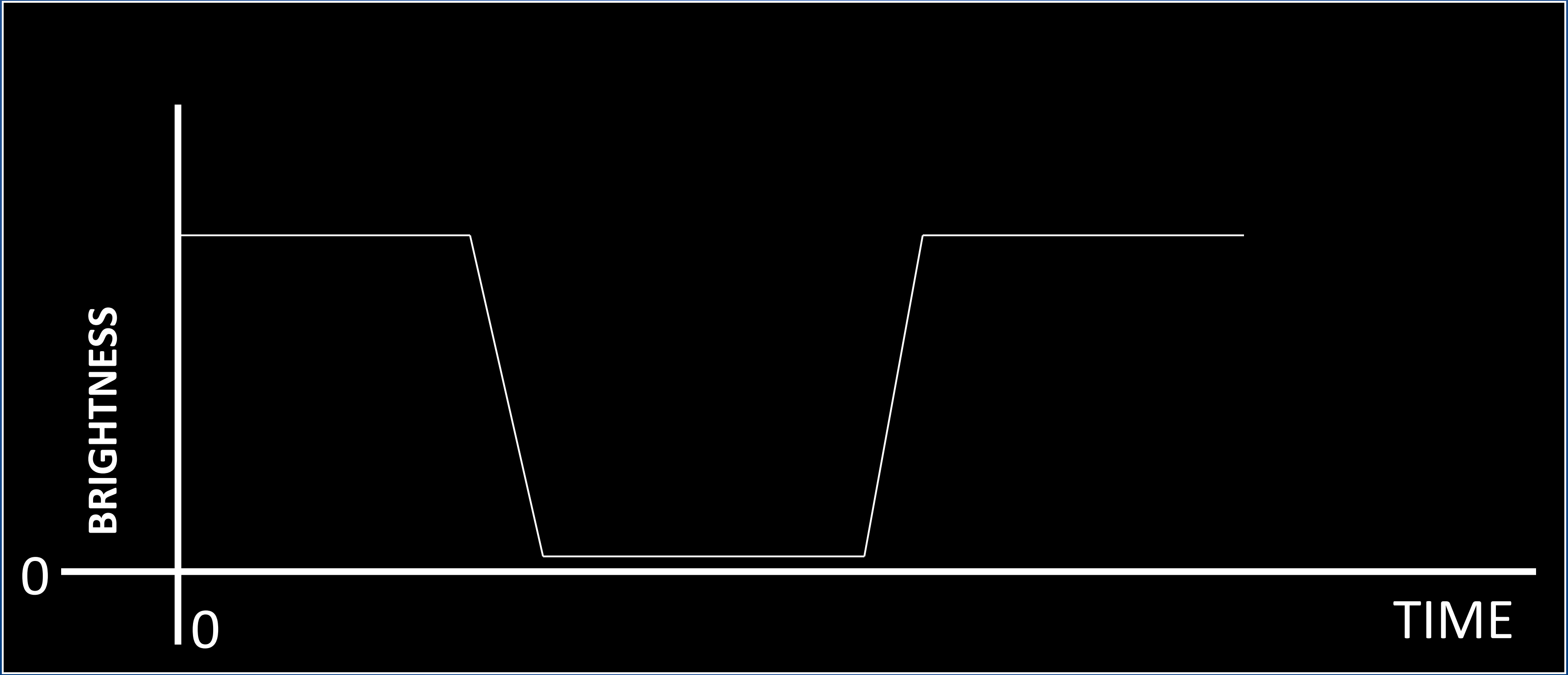
A Search for Habitable Planets

Imagine you have a light sensor aimed a lamp.

What would the transit of a book look like if you made a graph of brightness vs time?

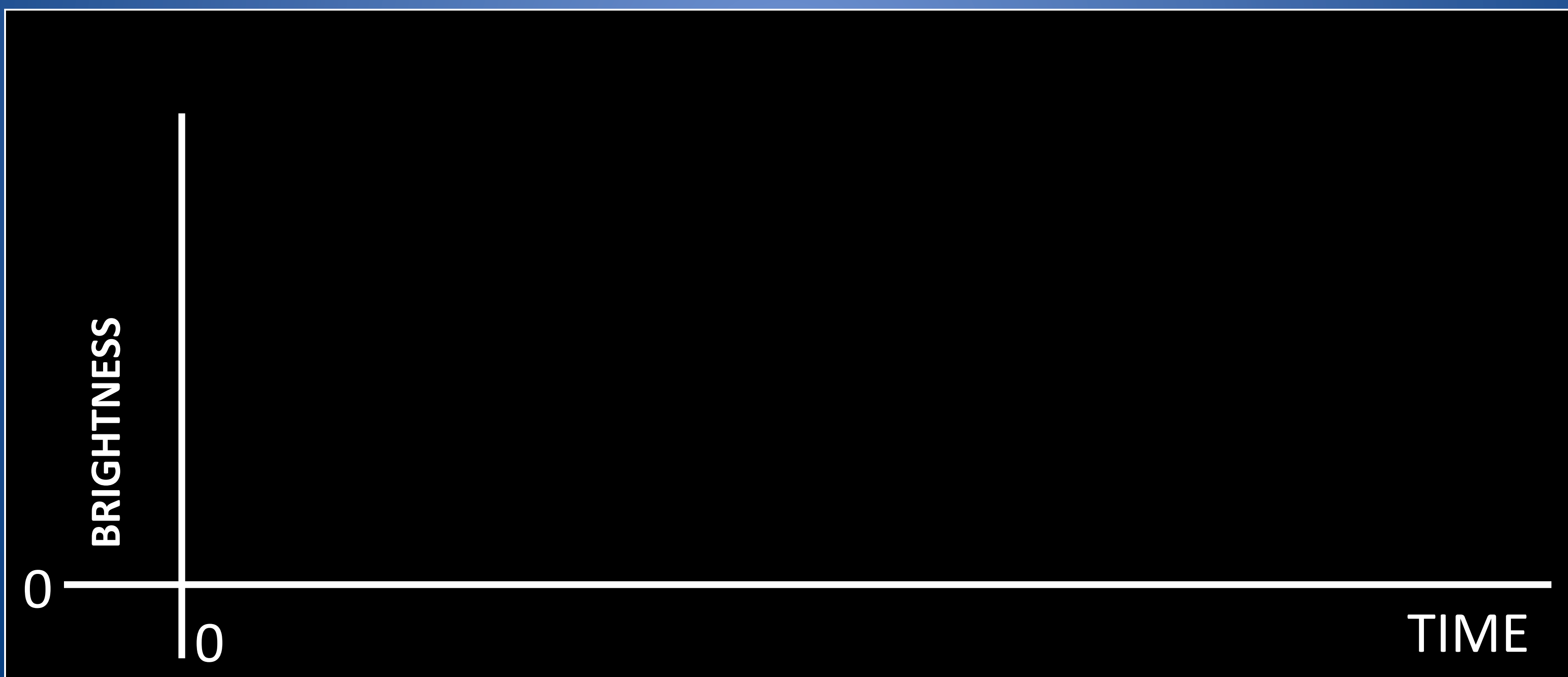
A Search for Habitable Planets

Like this?



A Search for Habitable Planets

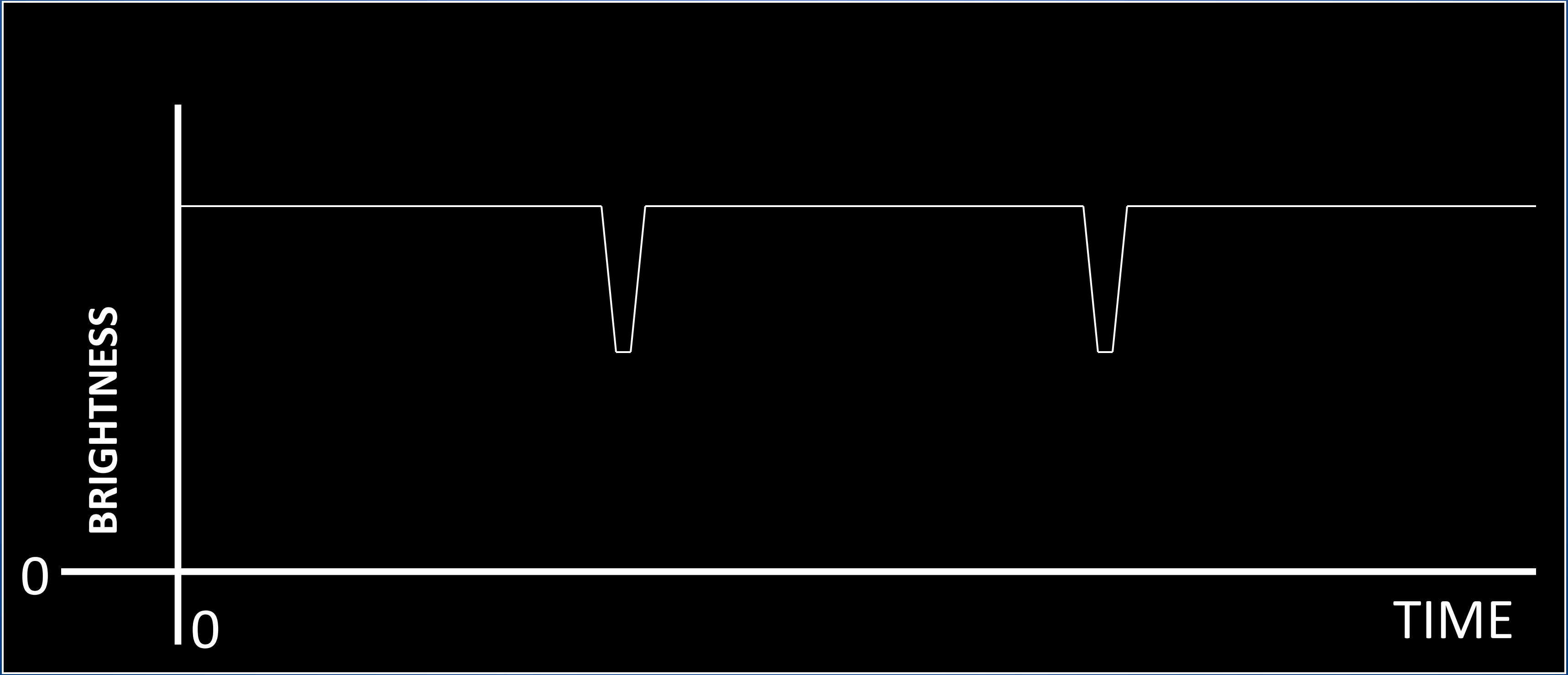
What would the transit of a planet look like if you made a graph brightness vs time?



A Search for Habitable Planets

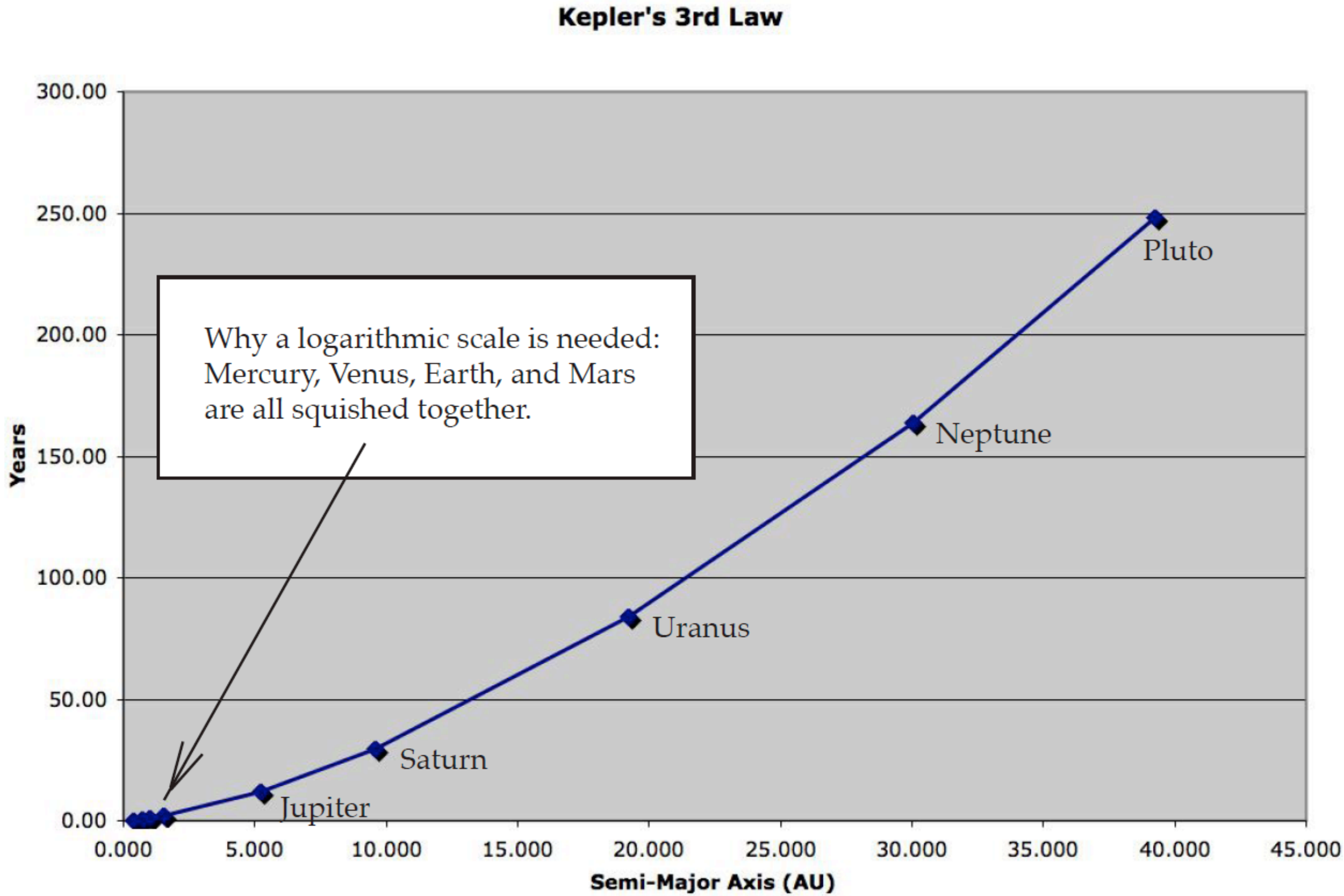
This is a “light curve.”

How are the planet’s size and orbital period shown in the light curve?

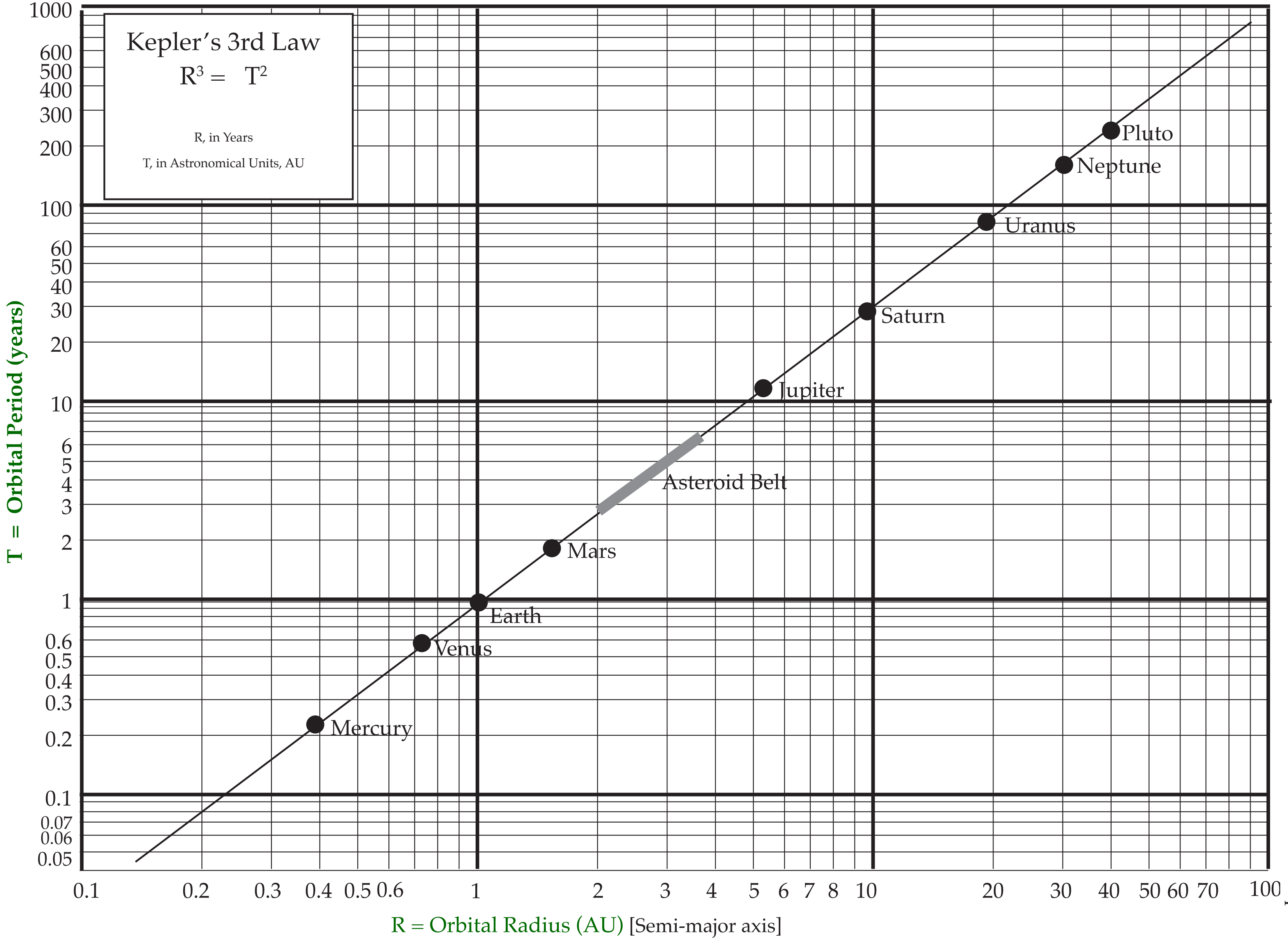


Is there a relationship between the planet’s period
(time for one orbit)
and
its distance from its star?

Linear Plot: Kepler's 3rd Law

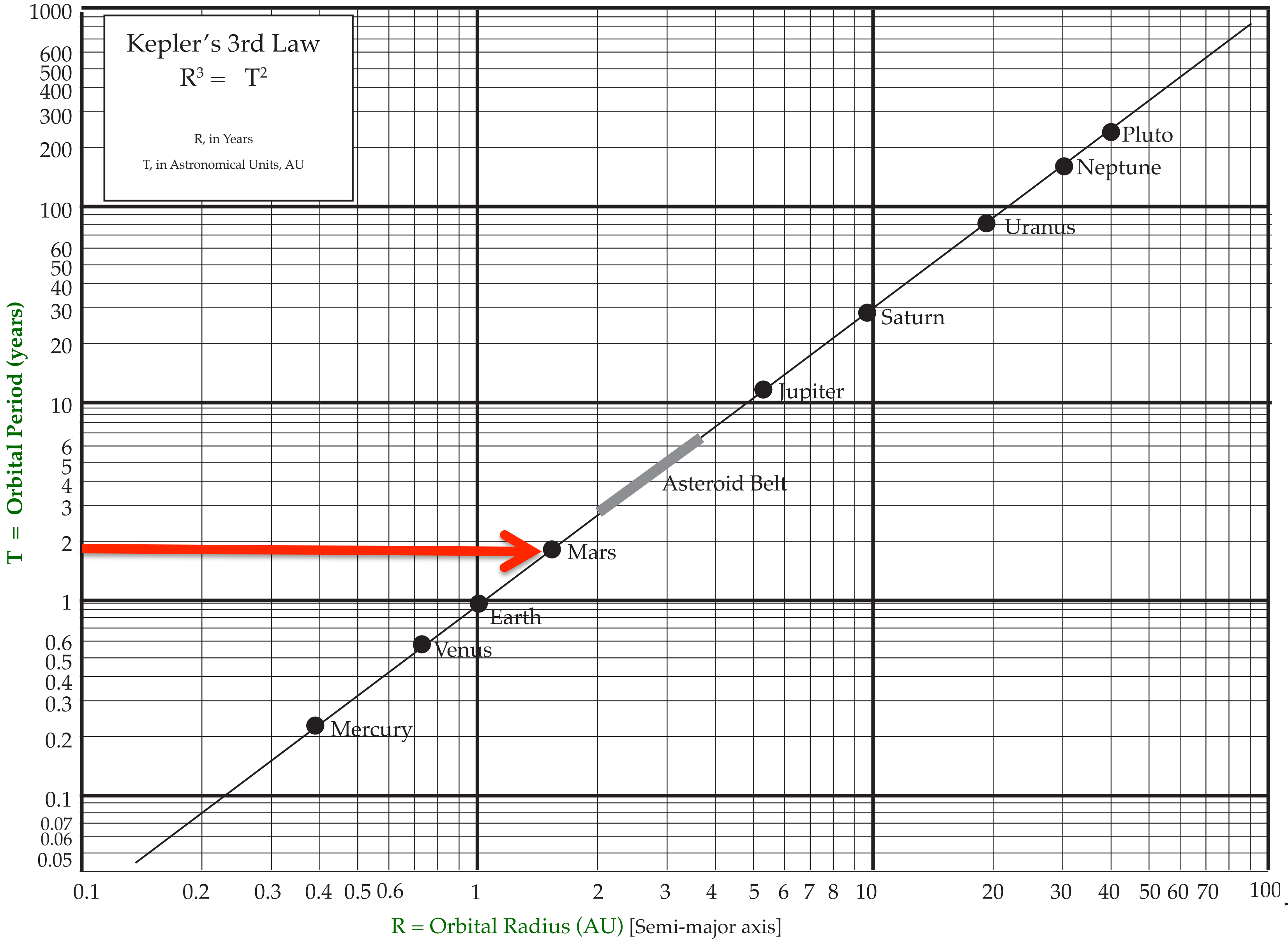


Keplers's 3rd Law Graph of Whole Solar System with Logarithmic Scales



Note: All objects -- planets, moons, asteroids, comets, meteoroids, dwarf planets -- all obey Kepler's 3rd Law.

Keplers's 3rd Law Graph of Whole Solar System with Logarithmic Scales



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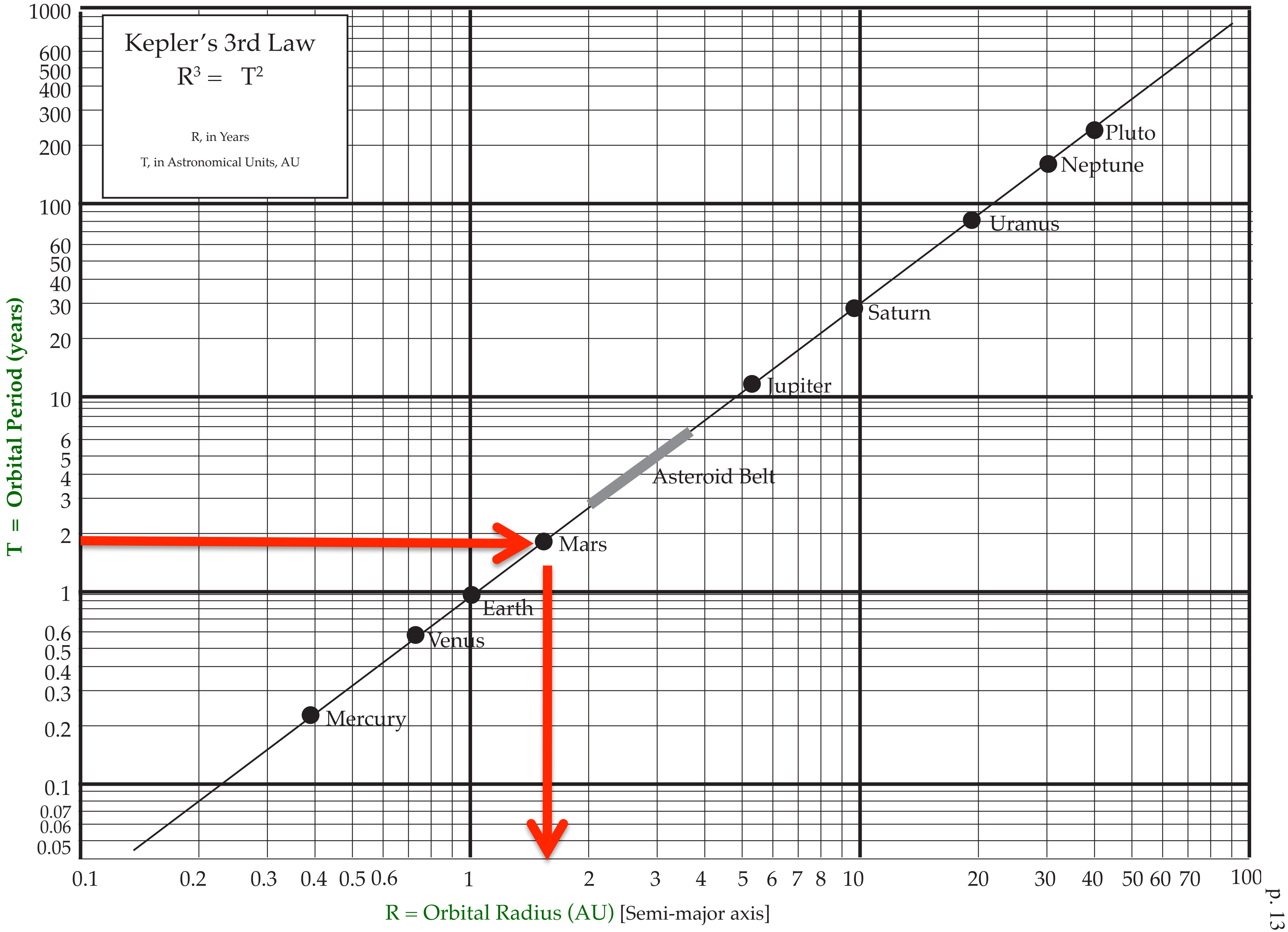

Note: All objects -- planets, moons, asteroids, comets, meteoroids, dwarf planets -- all obey Kepler's 3rd Law.

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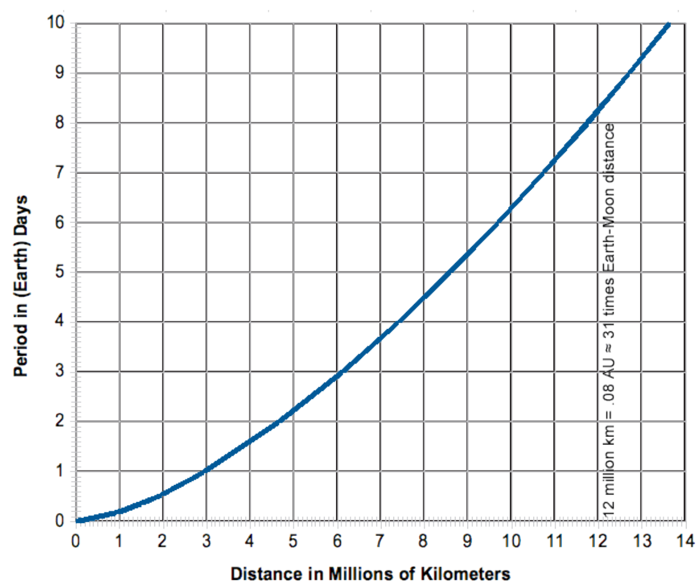
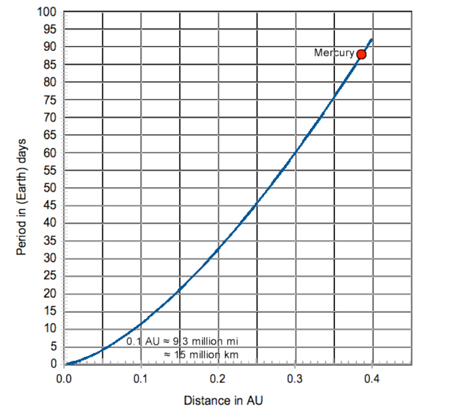
Kepler's 3rd Law Graphs

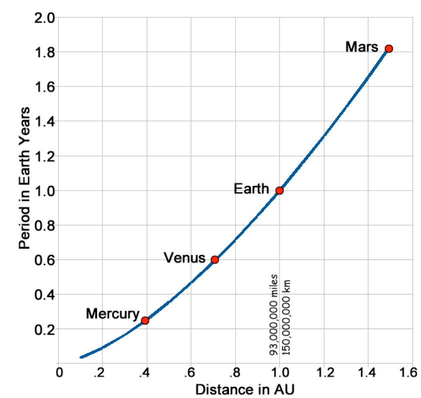
Kepler's 3rd Law Graph for Periods less than 10 days



Kepler's 3rd Law Graph for Periods Less Than 100 Days



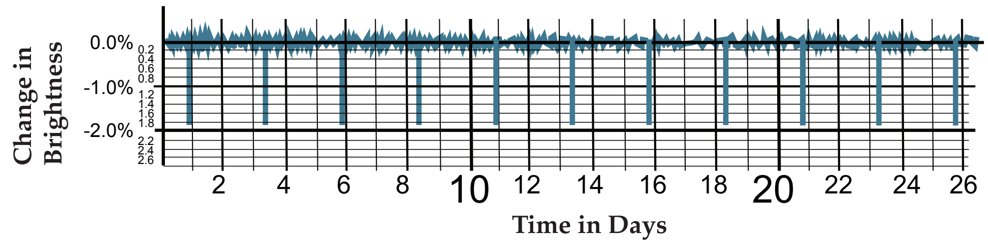
Kepler's 3rd Law Graph for the Inner Solar System
(periods less than 2 years)



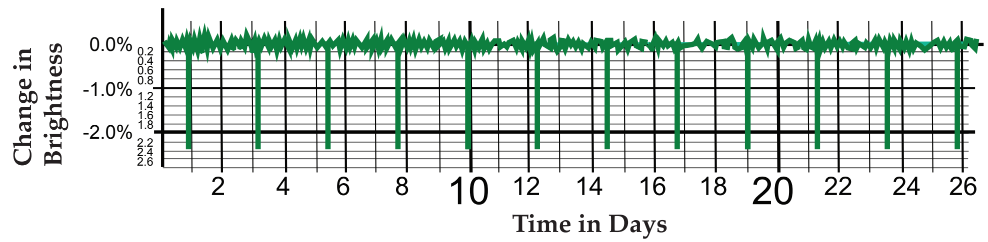
h for Habitable Planets

Transit Light Curves

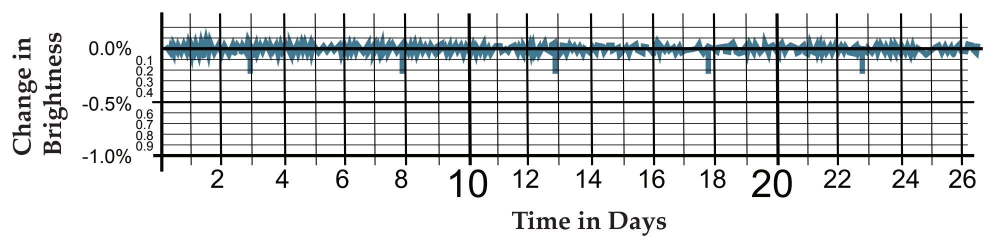
Kepler-1b (TrES-2)



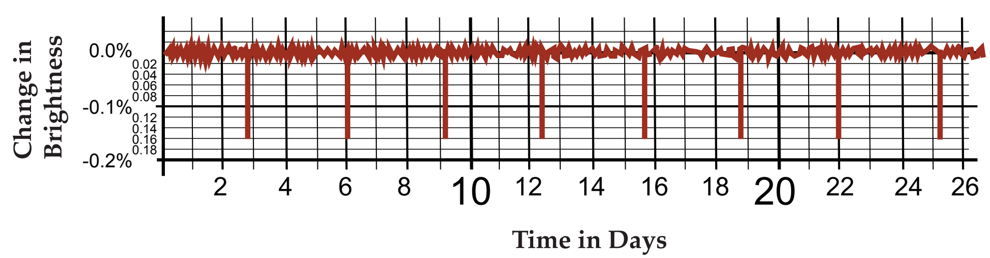
Kepler-2b (HAT-P 7b)



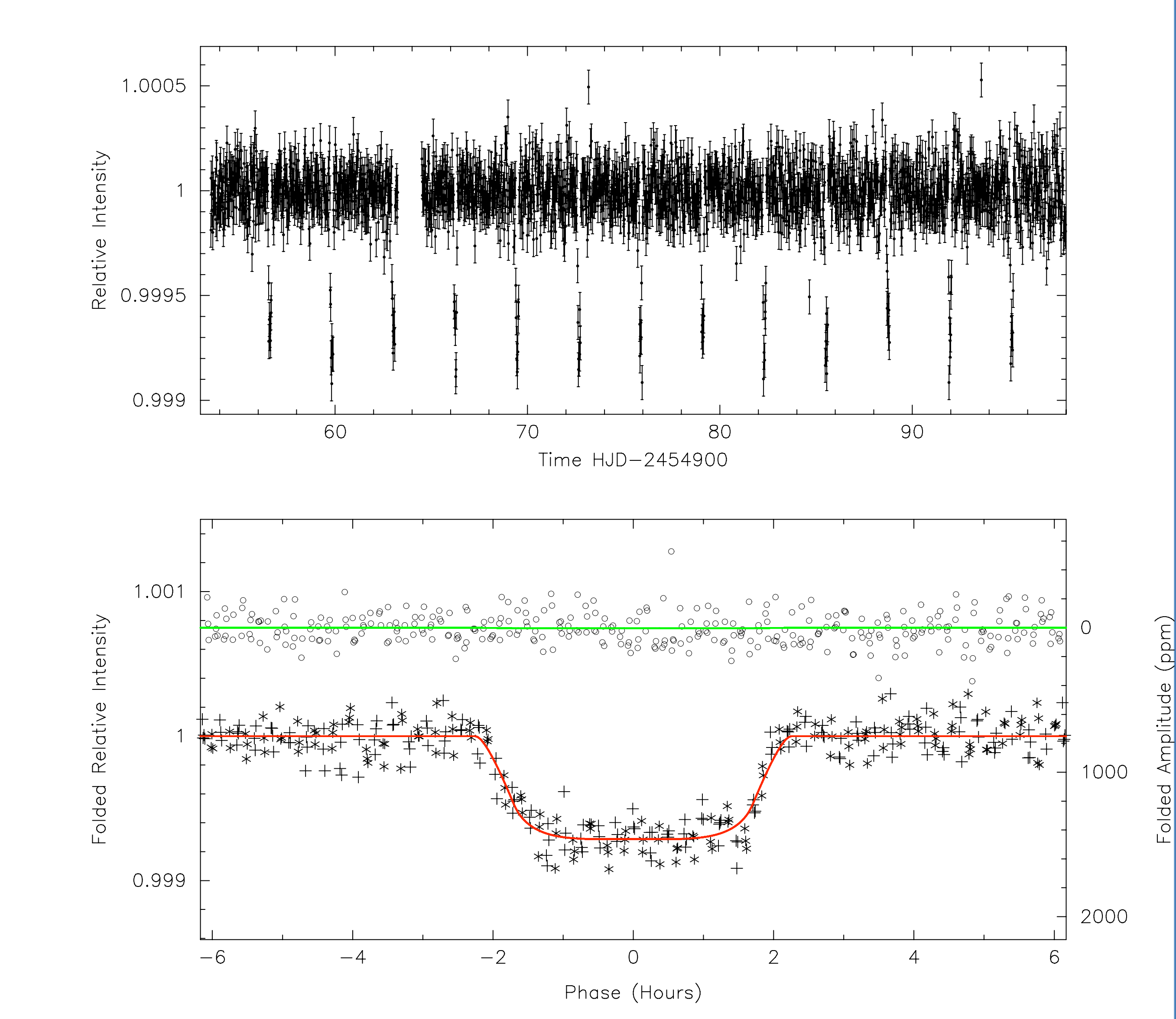
Kepler-3b (HAT-P-11b)



Kepler-4b

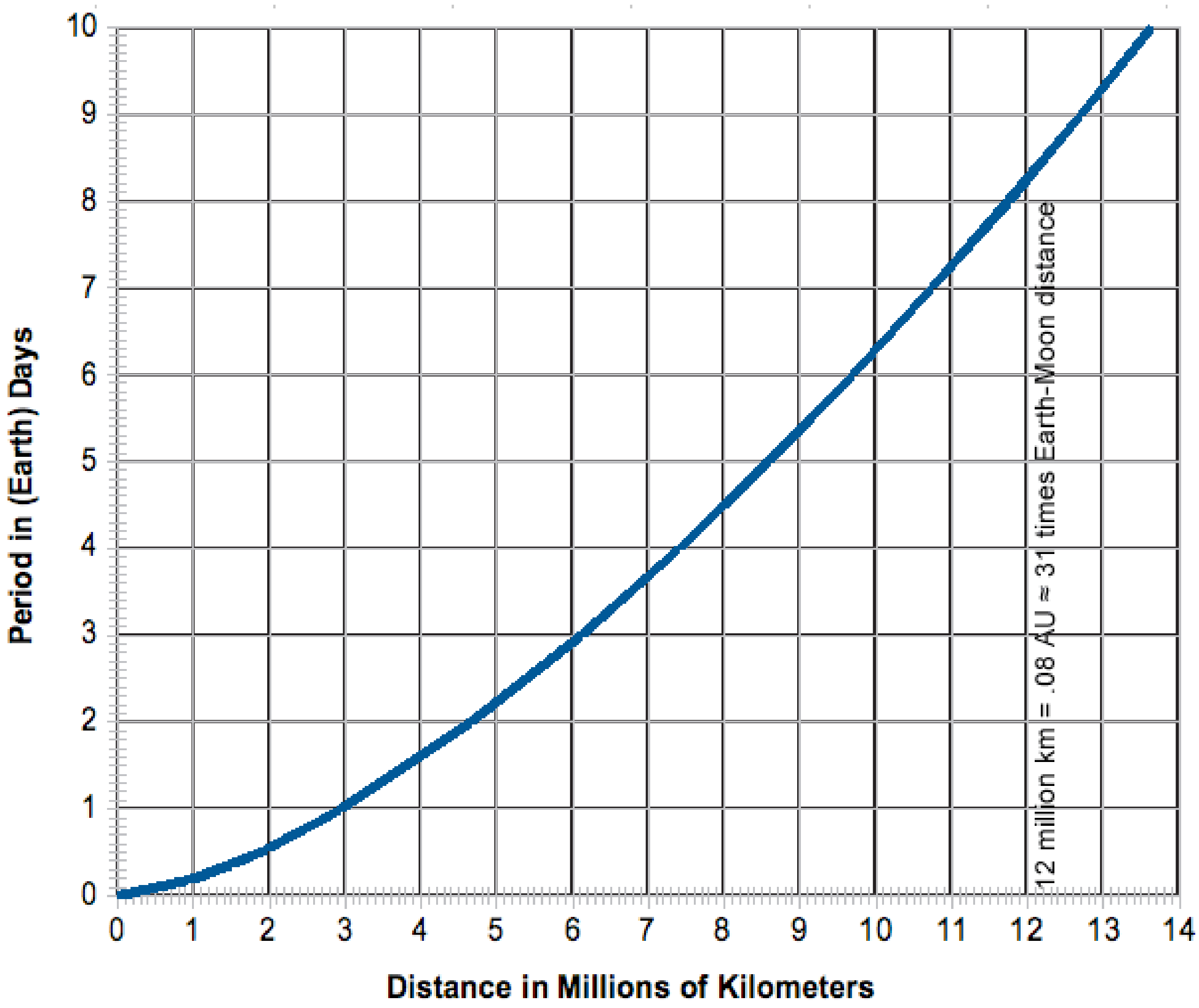


A Search for Habitable Planets



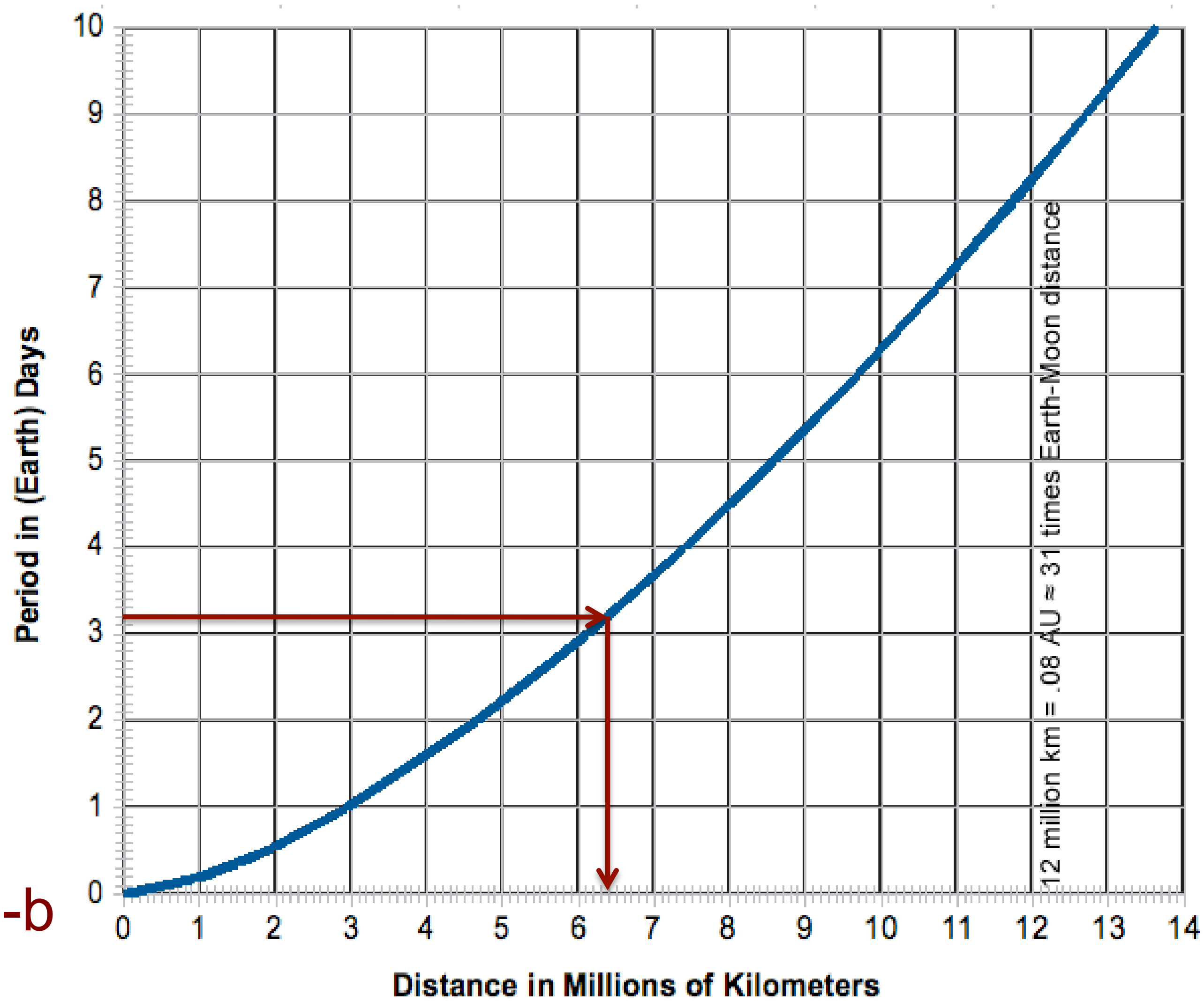
A Search for Habitable Planets

Kepler's 3rd Law Graph for Periods less than 10 days



A Search for Habitable Planets

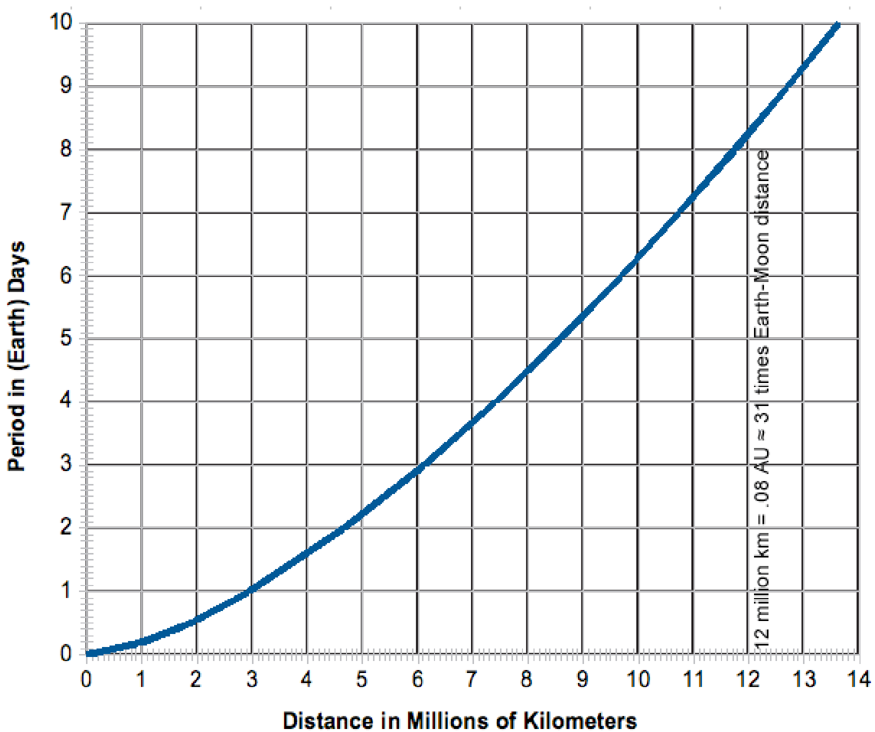
Kepler's 3rd Law Graph for Periods less than 10 days



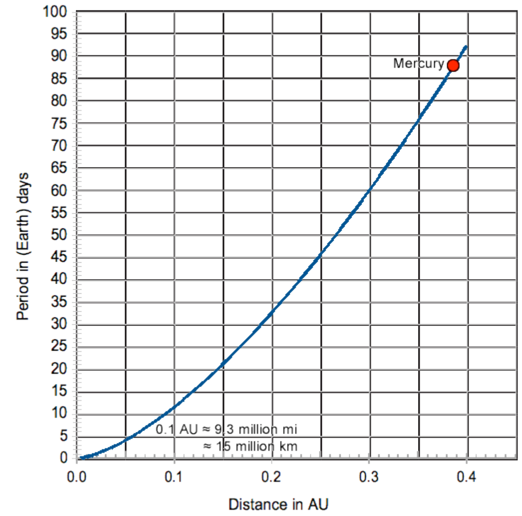
Kepler 4-b

Kepler's 3rd Law Graphs

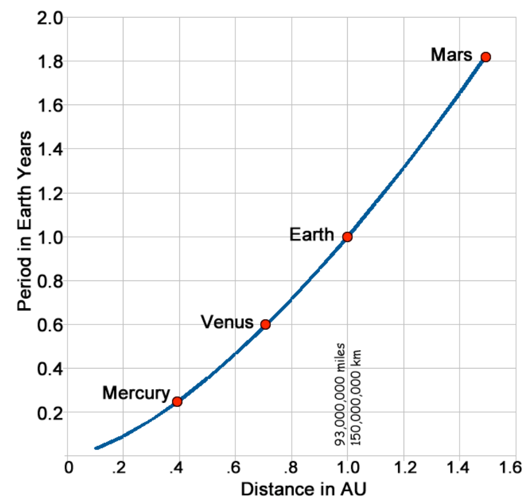
Kepler's 3rd Law Graph for Periods less than 10 days



Kepler's 3rd Law Graph for Periods Less Than 100 Days

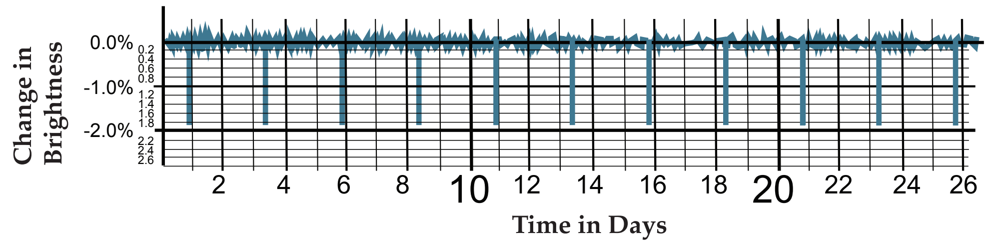


Kepler's 3rd Law Graph for the Inner Solar System (periods less than 2 years)

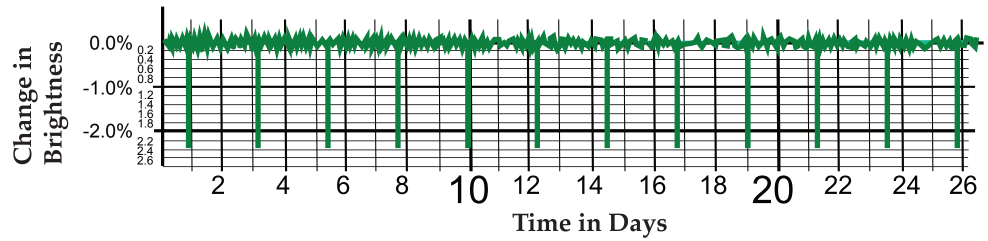


Transit Light Curves

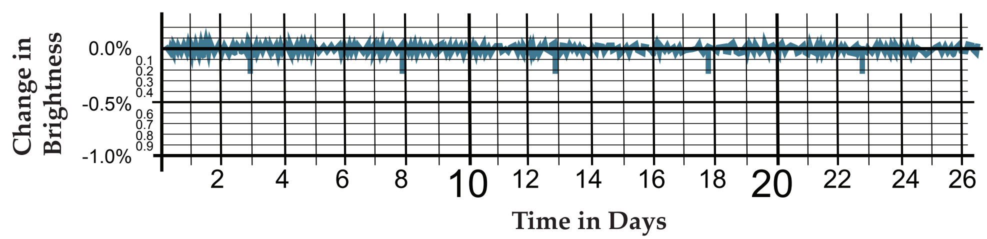
Kepler-1b (TrES-2)



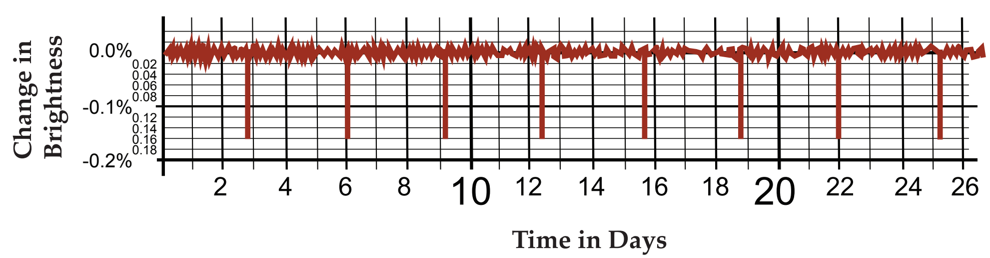
Kepler-2b (HAT-P 7b)



Kepler-3b (HAT-P-11b)

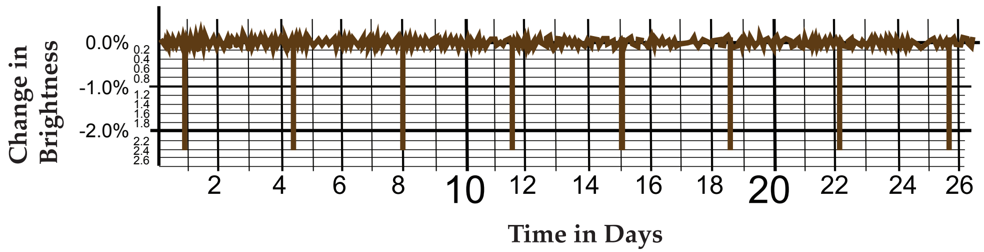


Kepler-4b

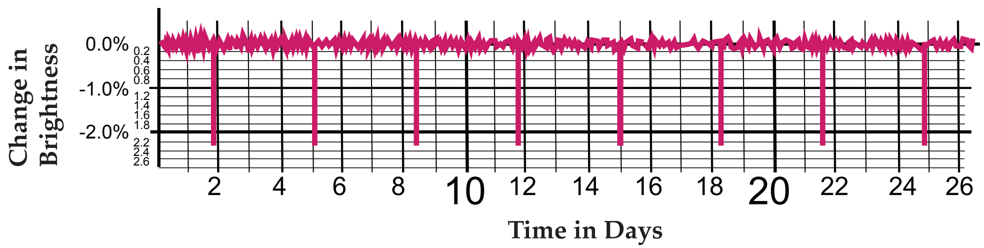


Transit Light Curves

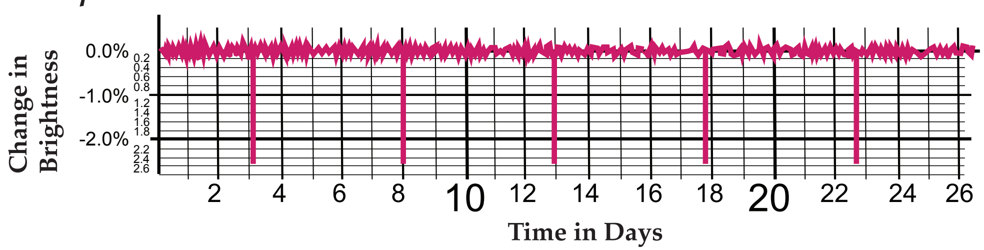
Kepler-5b



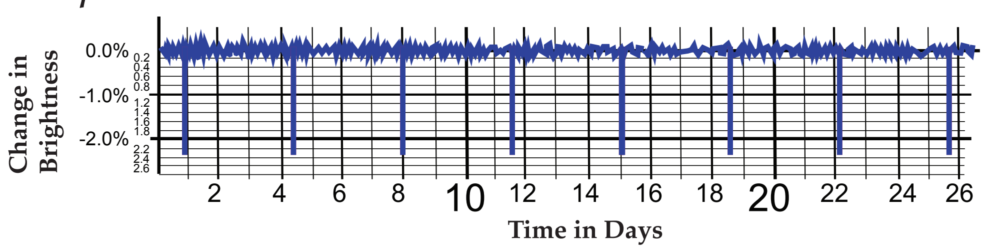
Kepler-6b



Kepler-7b



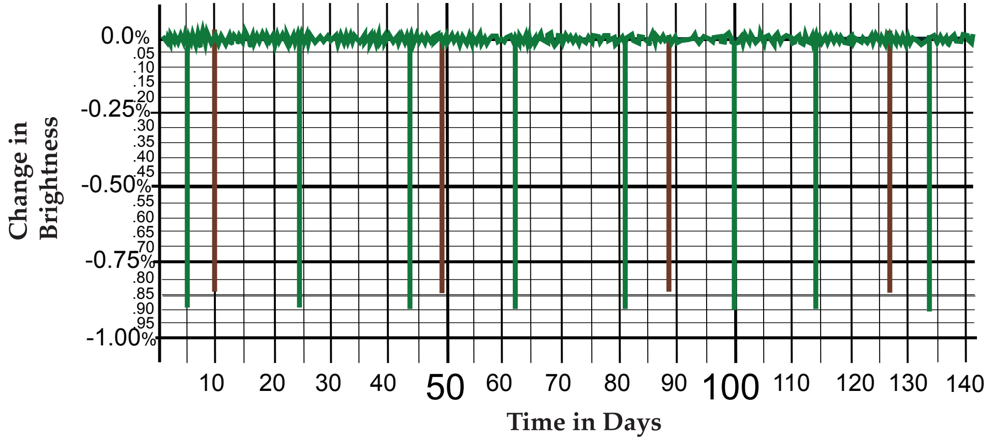
Kepler-8b



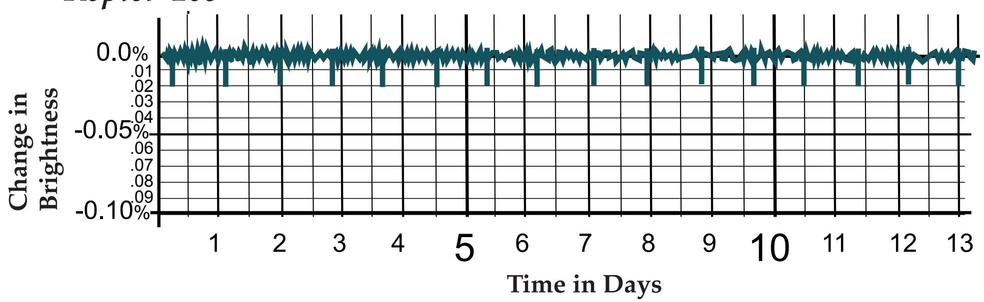
for Habitable Planets

Transit Light Curves

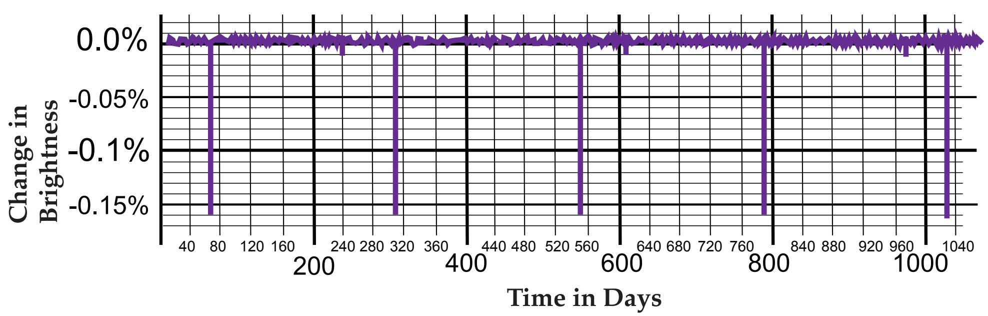
Kepler-9b, 9c



Kepler-10b

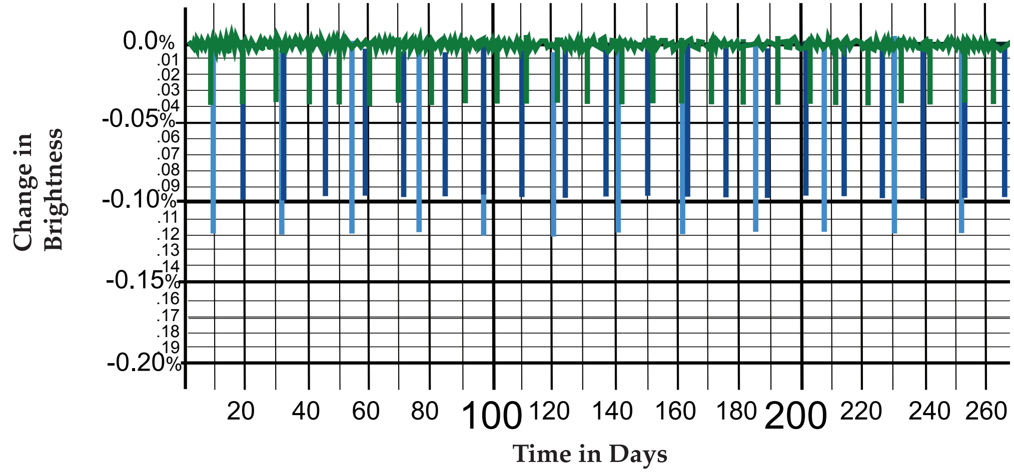


Mystery

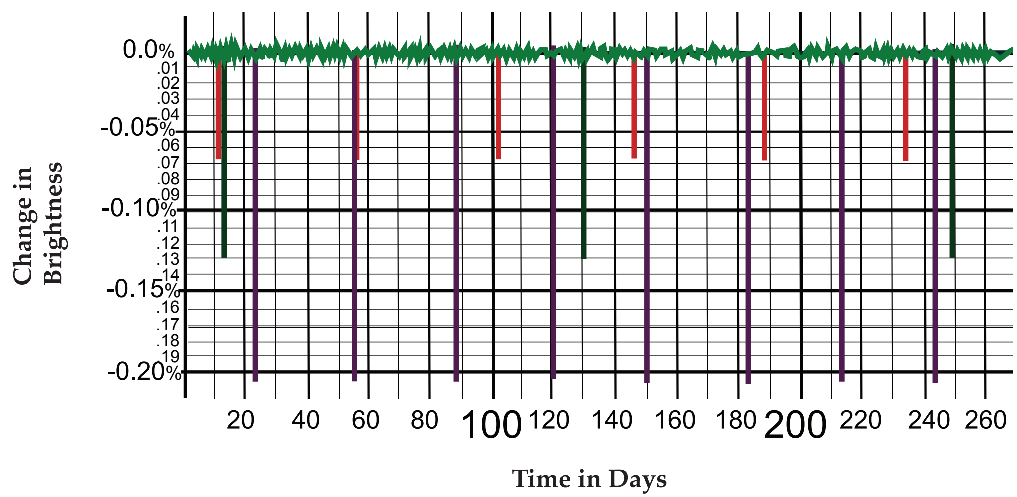


Transit Light Curves

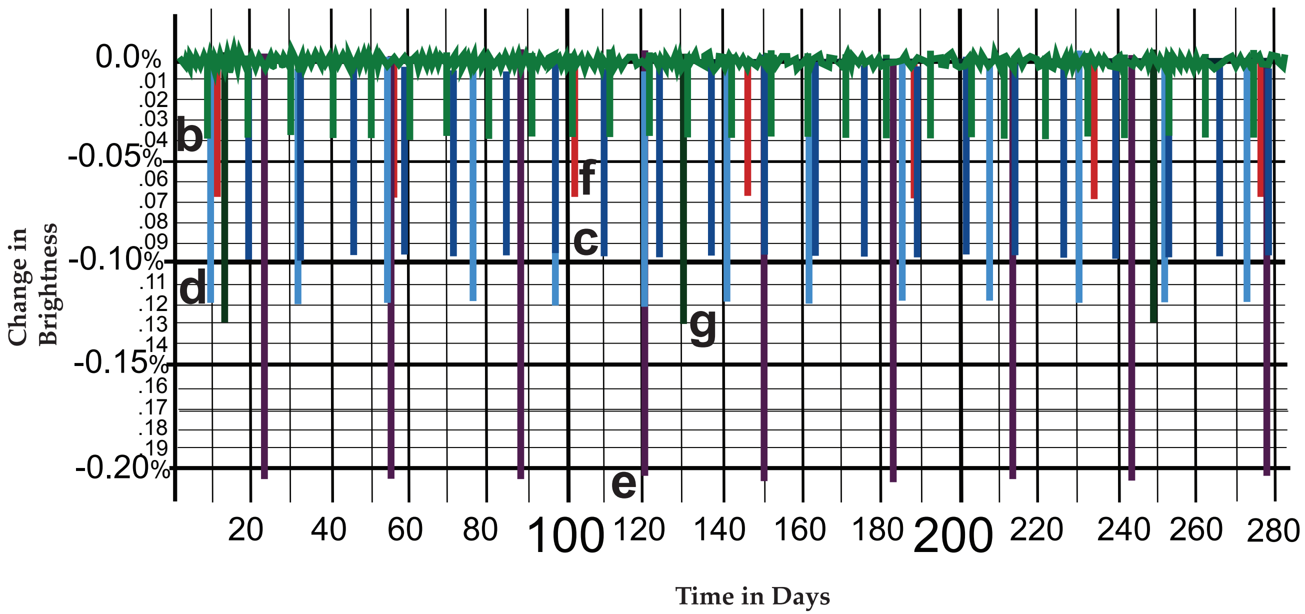
Kepler-11b, 11c, 11d



Kepler-11e, 11f, 11g



Kepler-11b, 11c, 11d, 11e, 11f, 11g



h for Habitable Planets

Analyzing Light Curves

Names: ____

Instructions: The "Transit Light Curves" are graphs of NASA's Kepler Mission's observations of stars. They show how the light level changes when a planet transits in front of a star. Study the light curves to find the period of the planet.The period is the time between transits and is year-length for a planet. Use "Kepler's 3rd Law Graphs" to find the "Orbital Distance" of the planet from its parent star.

The "Planet's Size" is found by measuring the "Change in Brightness," the small percentage drop in the light level as the planet transits. Calculate the planet's radius using the formula in the table below.

Orbital Distance

(from Kepler's 3rd Law graph)

Planet Name	**Period** Units ________	**Orbital Distance** Units ___________

Planet's Size

(planet radius using formula)

Planet	**Brightness** Drop of Z (%)	$\sqrt{Z}$	**Radius = 10 x** $\sqrt{Z}$ (in Earth radii)

Questions:

1. Which planet(s) are similar in size to Earth?

2. Jupiter's radius is about 11 times Earth's radius. Which planets are similar in size to Jupiter?

3. Describe the relationship between the period of the planets and their orbital distances.

...h for Habitable Planets

Analyzing Light Curves: Calculated with Kepler's 3rd Law

Names: ______________________________

Instructions: The "Transit Light Curves" are graphs of NASA's Kepler Mission's observations of stars. They show how the light level changes when a planet transits in front of a star. Study the light curves to find the period of the planet. The period is the time between transits and equals year-length for a planet (T).

Like Johannes Kepler did, we express the planet's distance (R) in **A**stronomical **U**nits (AU). 1 AU is the average distance from the Earth to the Sun.

For stars the same size as the Sun, Kepler's 3rd Law is simply:

$$R^3 = T^2 \; * \quad \text{or} \quad R = \sqrt[3]{T^2 \cdot Ms}$$

For the Sun, Ms = 1. For other stars, Ms is mass in relationship to the Sun's mass.

The "Planet's Size" is determined by measuring the "Change in Brightness," the percentage drop in the light level as the planet transits. Calculate the planet's radius using the formula in the table below.

* *Note: There is actually a constant K implied in this equation that sets the units straight:*
$R^3/T^2 = K$ *where* $K = 1\ AU^3/Year^2$

Orbital Distance
from Kepler's 3rd Law

Planet	Period (T) (T in years)	T^2	Ms	$R = \sqrt[3]{T^2 Ms}$ (in AU)

Planet's Size
(radius using formula)

Planet	Brightness Drop of Z (%)	$\sqrt{Z}$	Radius = $10 \times \sqrt{Z}$ (in Earth radii)

CUBE ROOTS

Number	Cube Root
0.0025	0.136
0.0050	0.171
0.0075	0.196
0.0010	0.100
0.0100	0.215
0.02	0.271
0.03	0.311
0.04	0.342
0.05	0.368
0.06	0.391
0.07	0.412
0.08	0.431

Number	Cube Root
0.09	0.448
0.1	0.464
0.12	0.493
0.14	0.519
0.16	0.543
0.18	0.565
0.2	0.585
0.22	0.604
0.24	0.621
0.26	0.638
0.28	0.654
0.3	0.669

Number	Cube Root
0.32	0.684
0.34	0.698
0.36	0.711
0.38	0.724
0.4	0.737
0.5	0.794
0.6	0.843
0.7	0.888
0.8	0.928
1	1.000

For cube-root calculator instructions:
http://kepler.nasa.gov/education/cuberoot/

Questions:

1. Which planet(s) are similar in size to Earth?

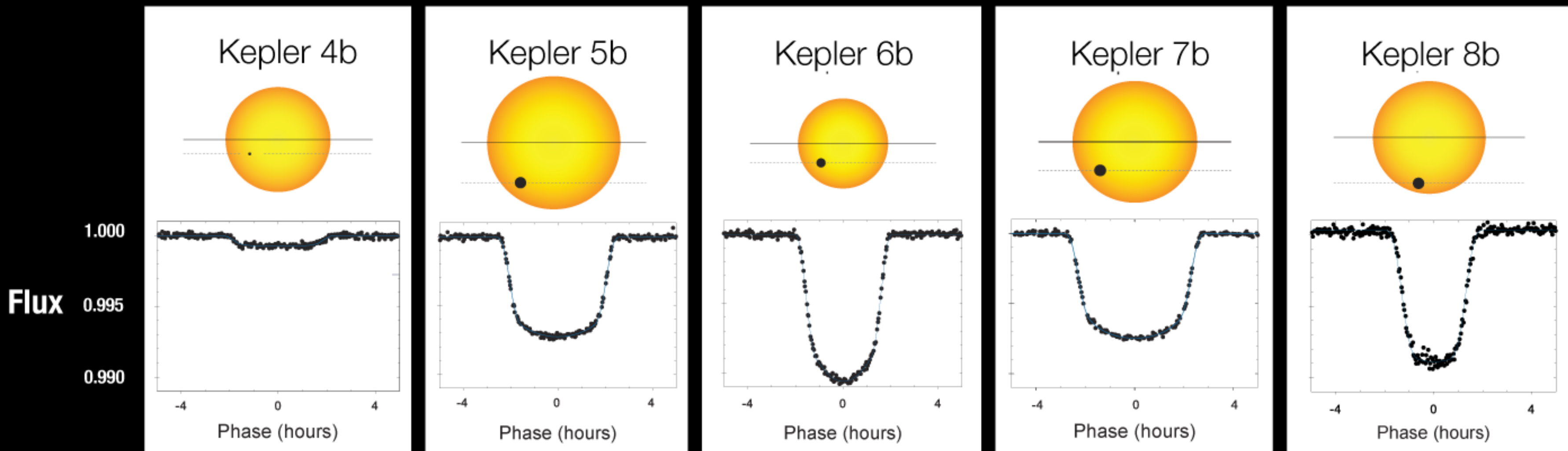
2. Jupiter's radius is about 11 times Earth's radius. Which planets are similar in size to Jupiter?

3. Describe the relationship between the period of the planets and their orbital distances.

A Search for Habitable Planets

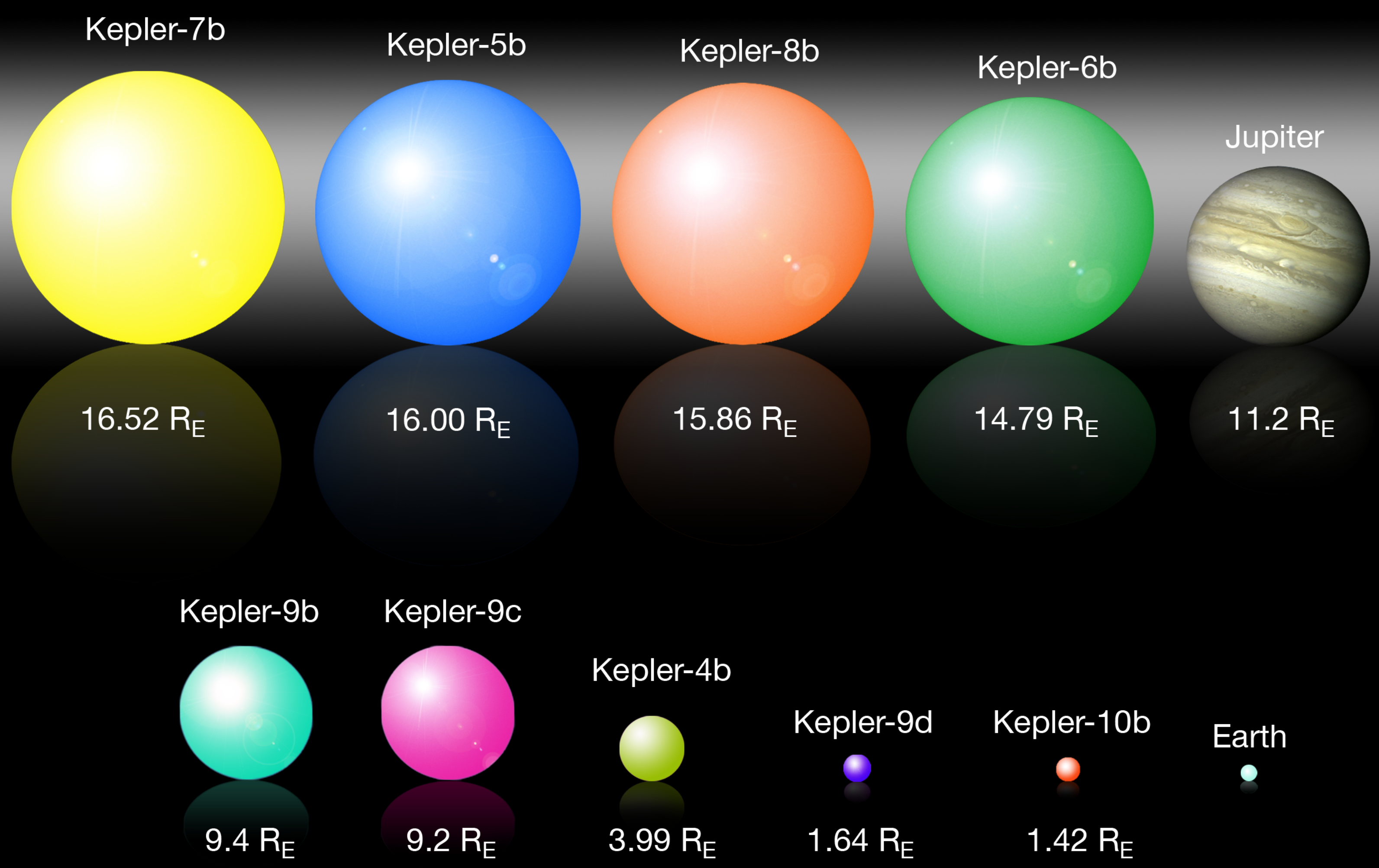
Planet Name	Period in days	Orbital Distance	Brightness Drop	$\sqrt{z}$	Radius = $10\sqrt{z}$

Transit Light Curves

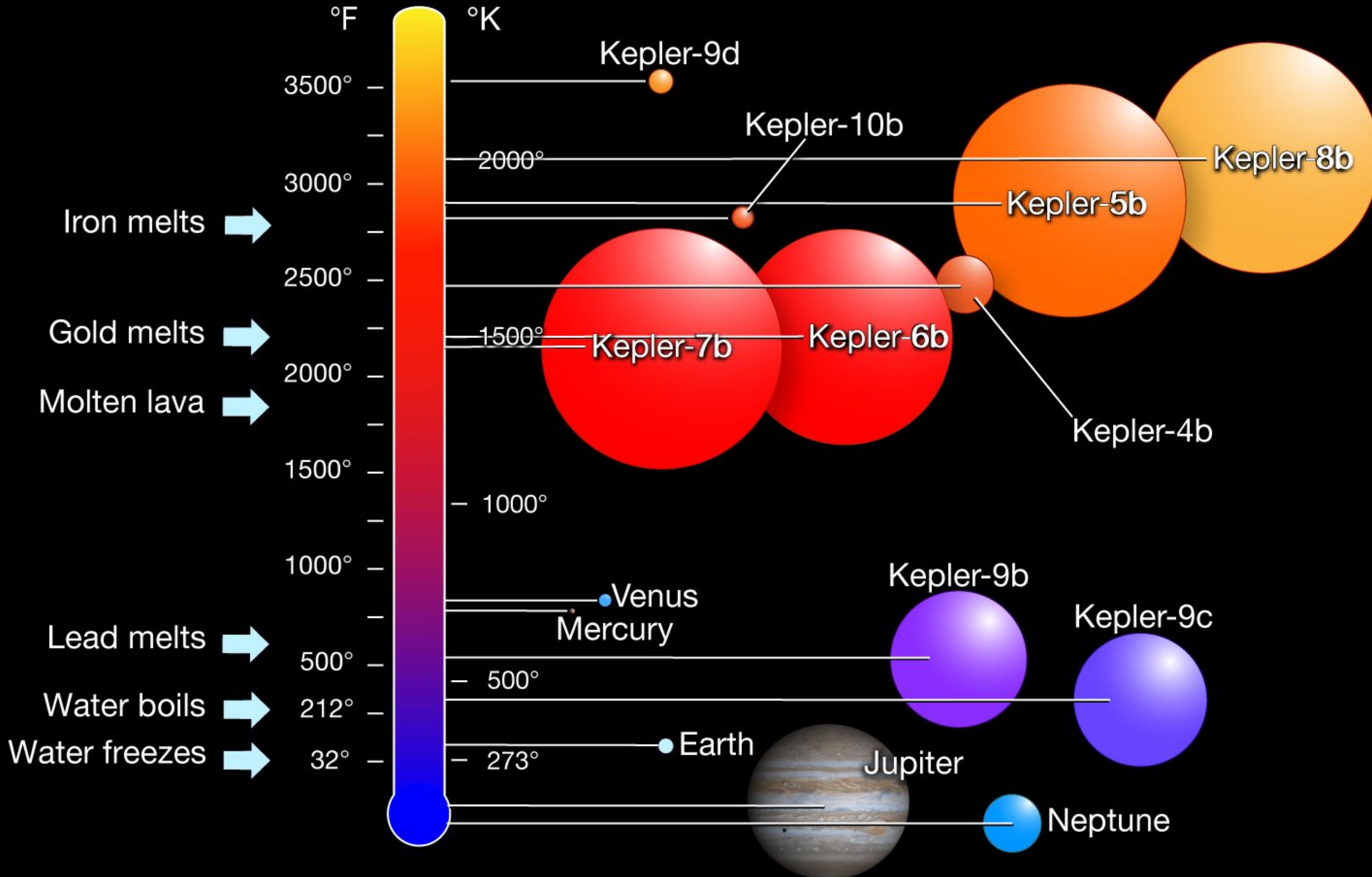


	Kepler 4b	Kepler 5b	Kepler 6b	Kepler 7b	Kepler 8b
Orbital Period (days)	*3.2 days*	*3.5 days*	*3.2 days*	*4.9 days*	*3.5 days*
Size (R_E)	*4.31*	*18.8*	*15.0*	*16.9*	*18.3*

Planet Size

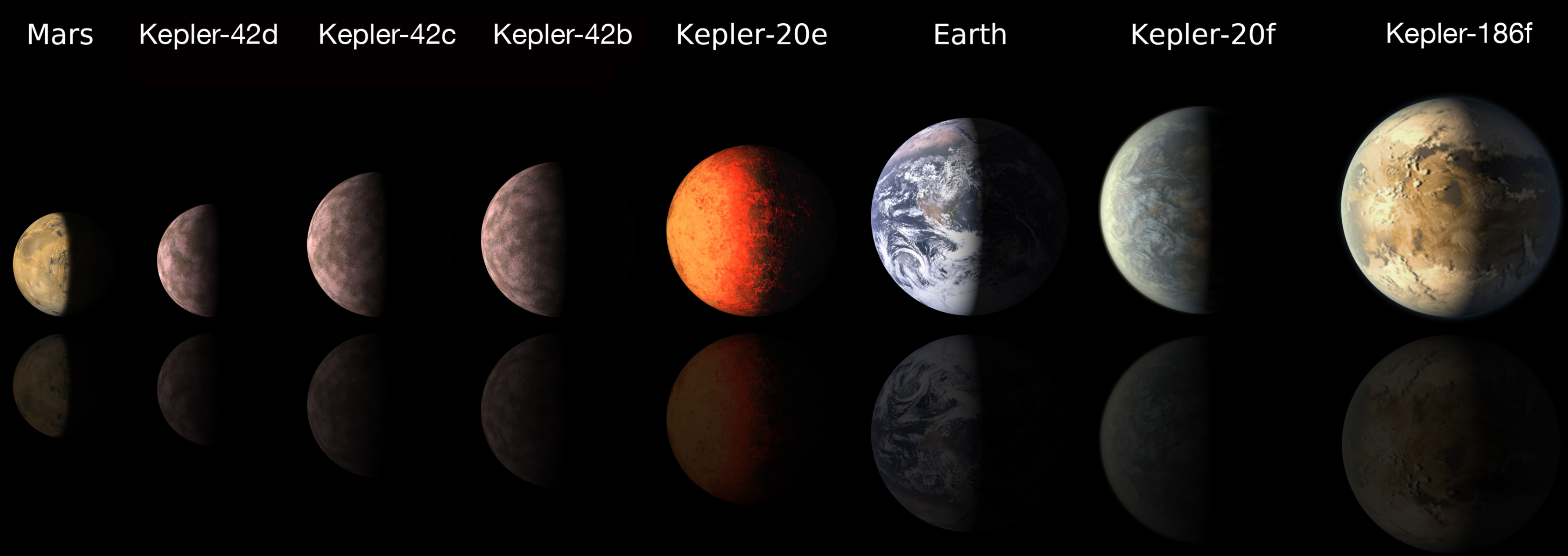

Kepler-7b
16.52 R_E
Kepler-5b
16.00 R_E
Kepler-8b
15.86 R_E
Kepler-6b
14.79 R_E
Jupiter
11.2 R_E
Kepler-9b
9.4 R_E
Kepler-9c
9.2 R_E
Kepler-4b
3.99 R_E
Kepler-9d
1.64 R_E
Kepler-10b
1.42 R_E
Earth

Planet Temperature & Size



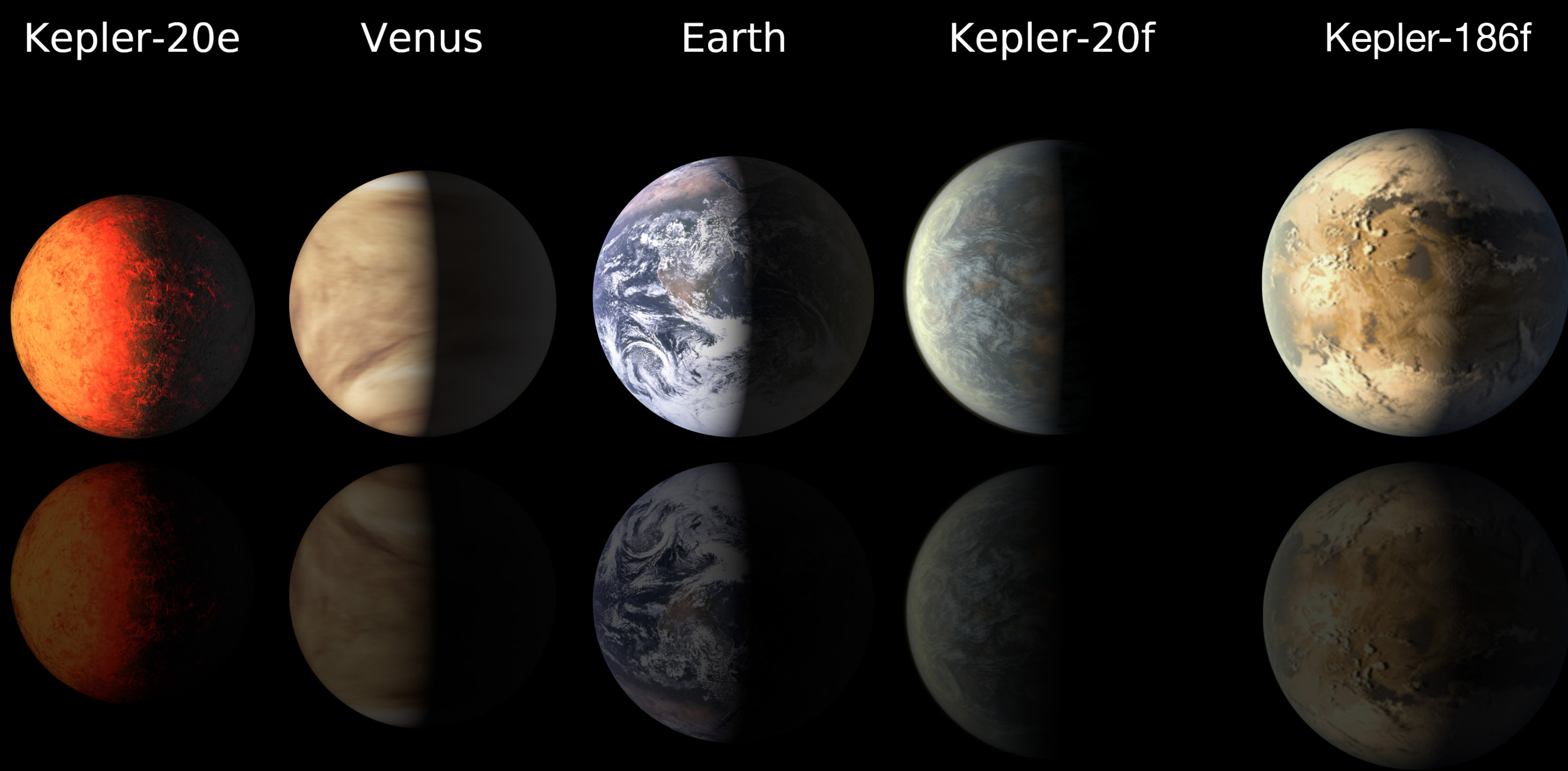
Planet Lineup

A Search for Habitable Planets



Planet Lineup

Kepler
A Search for Habitable Planets



Kepler's Planet Candidates

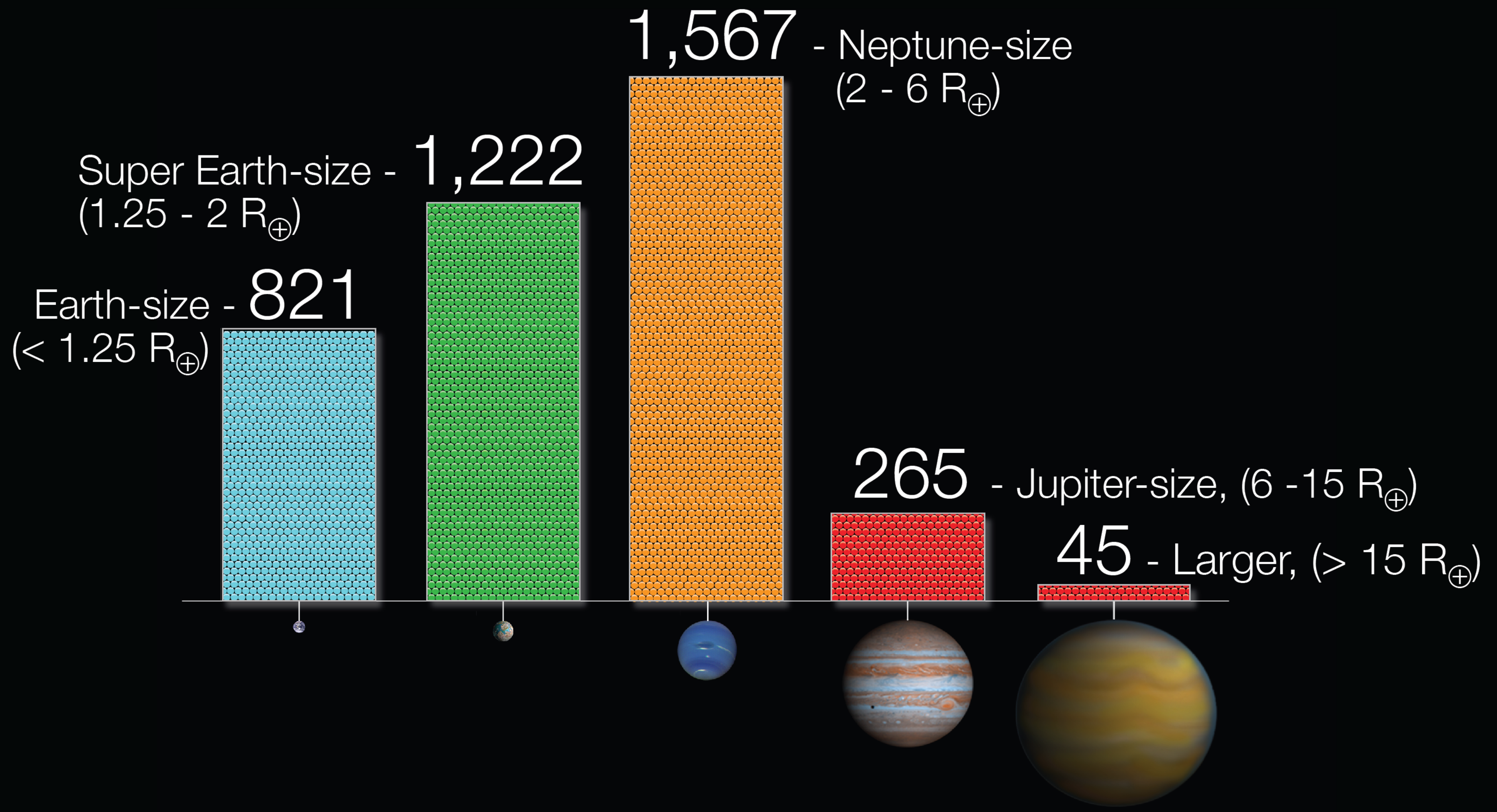
4,175 as of January 2015

By Location

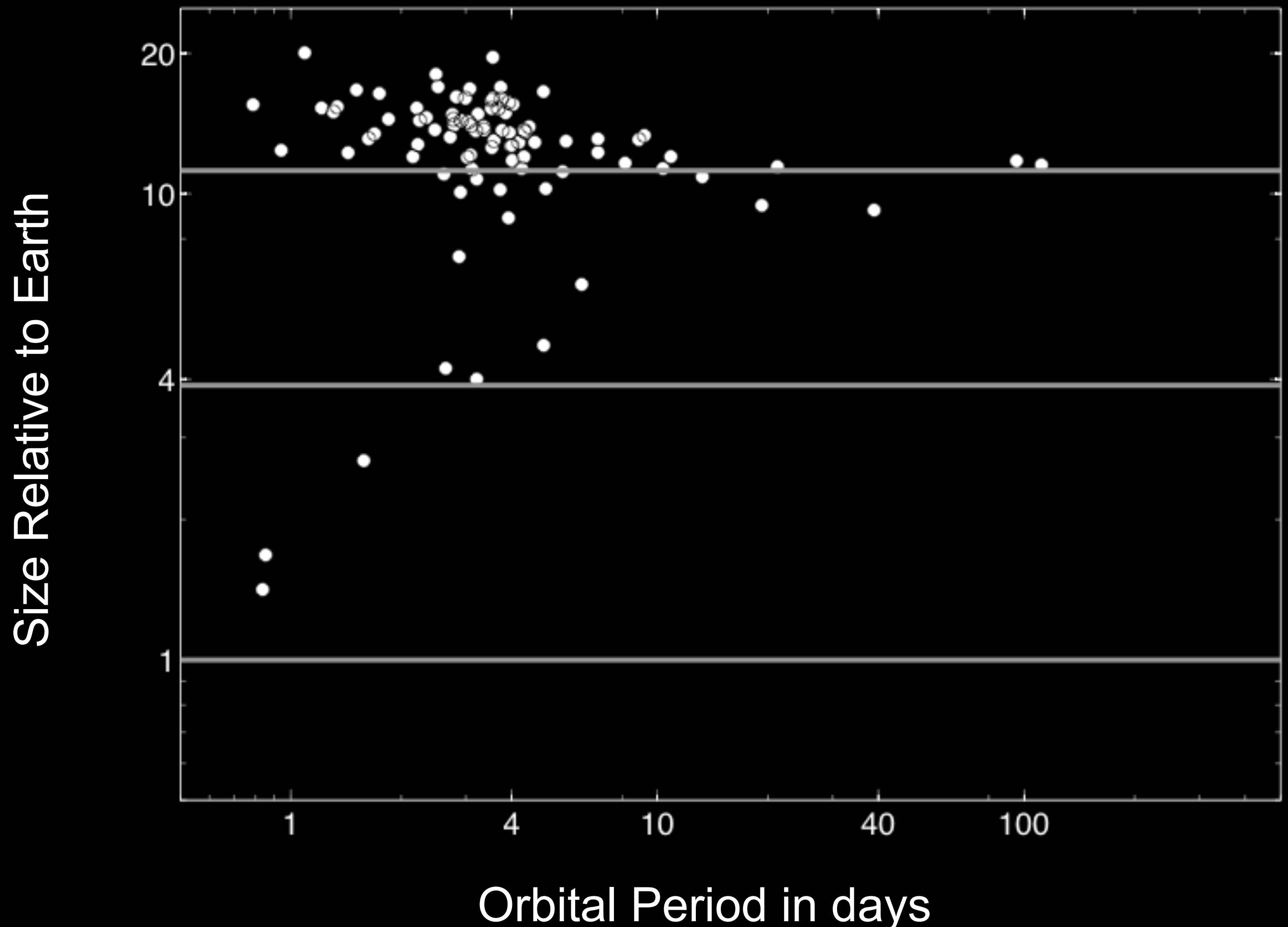
- Earth-size
- Super-Earth-size
- Neptune-size
- Jupiter-size and larger

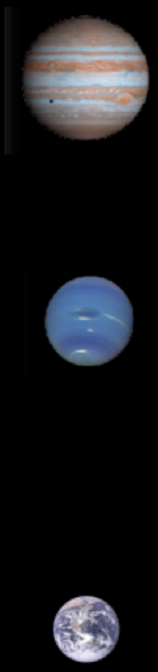
Sizes of Planet Candidates

Totals as of September 2014



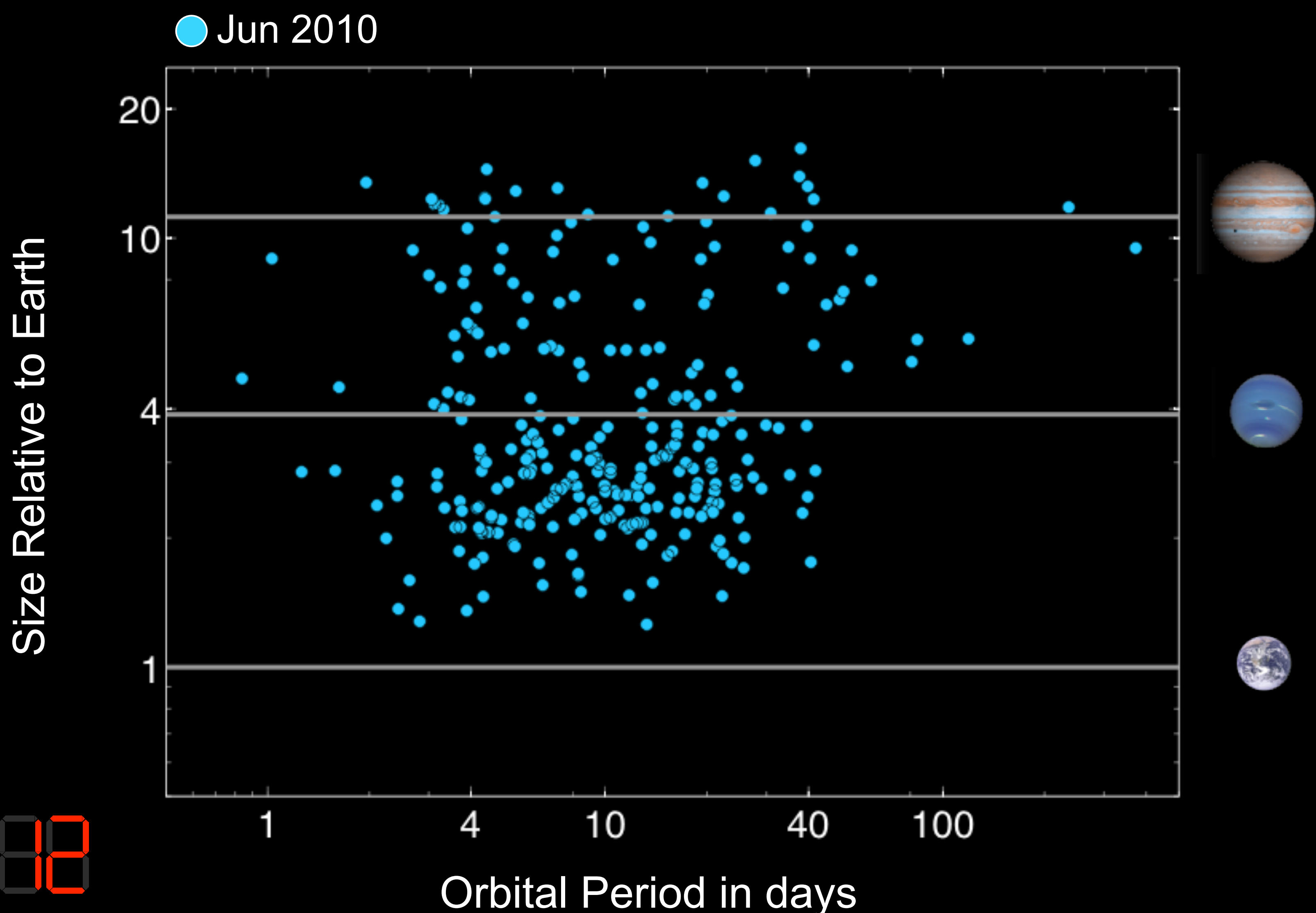
Transiting Planets pre-Kepler





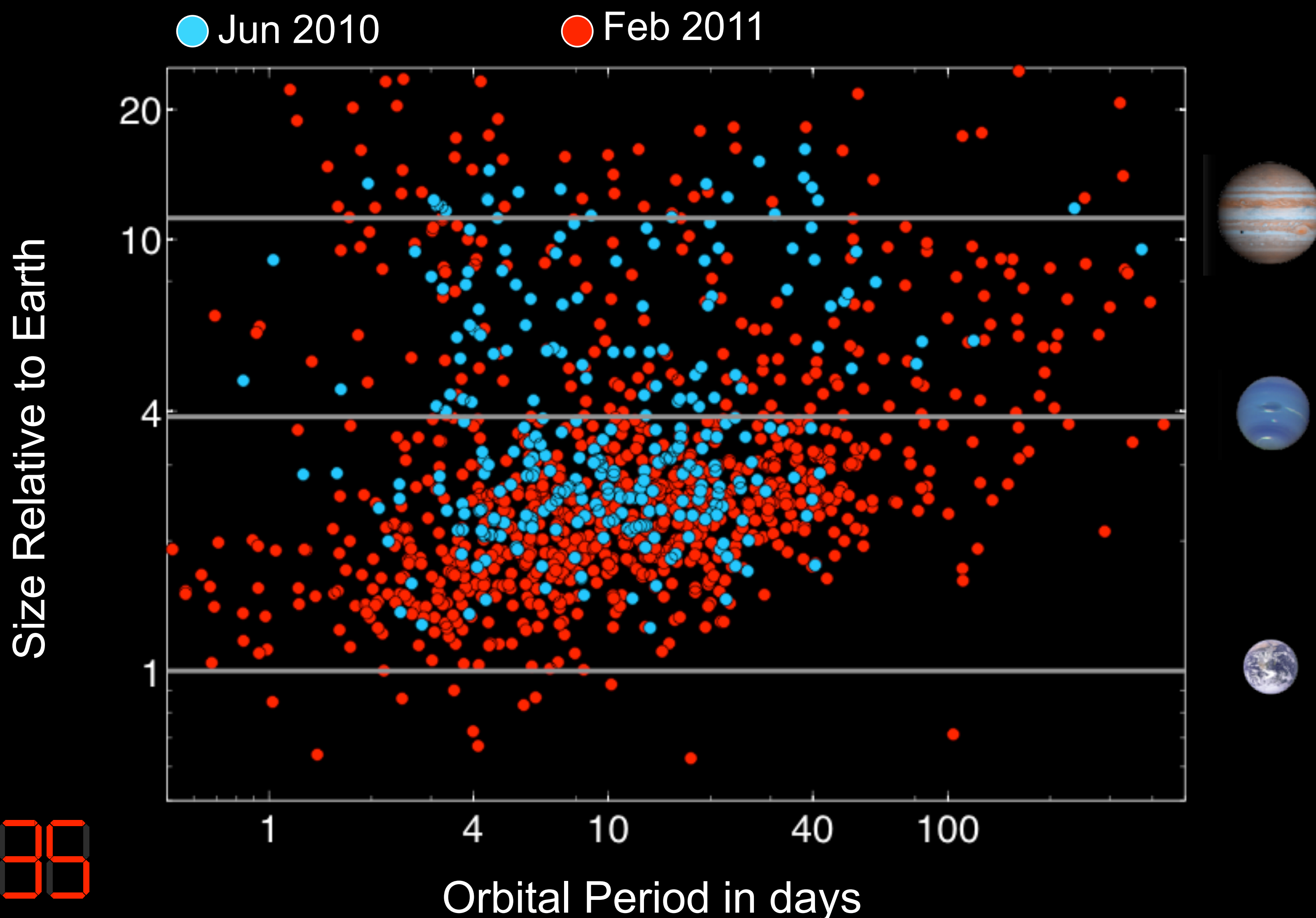
Candidates as of June 2010

Data: May-Sep 2009



Candidates as of Feb 2011

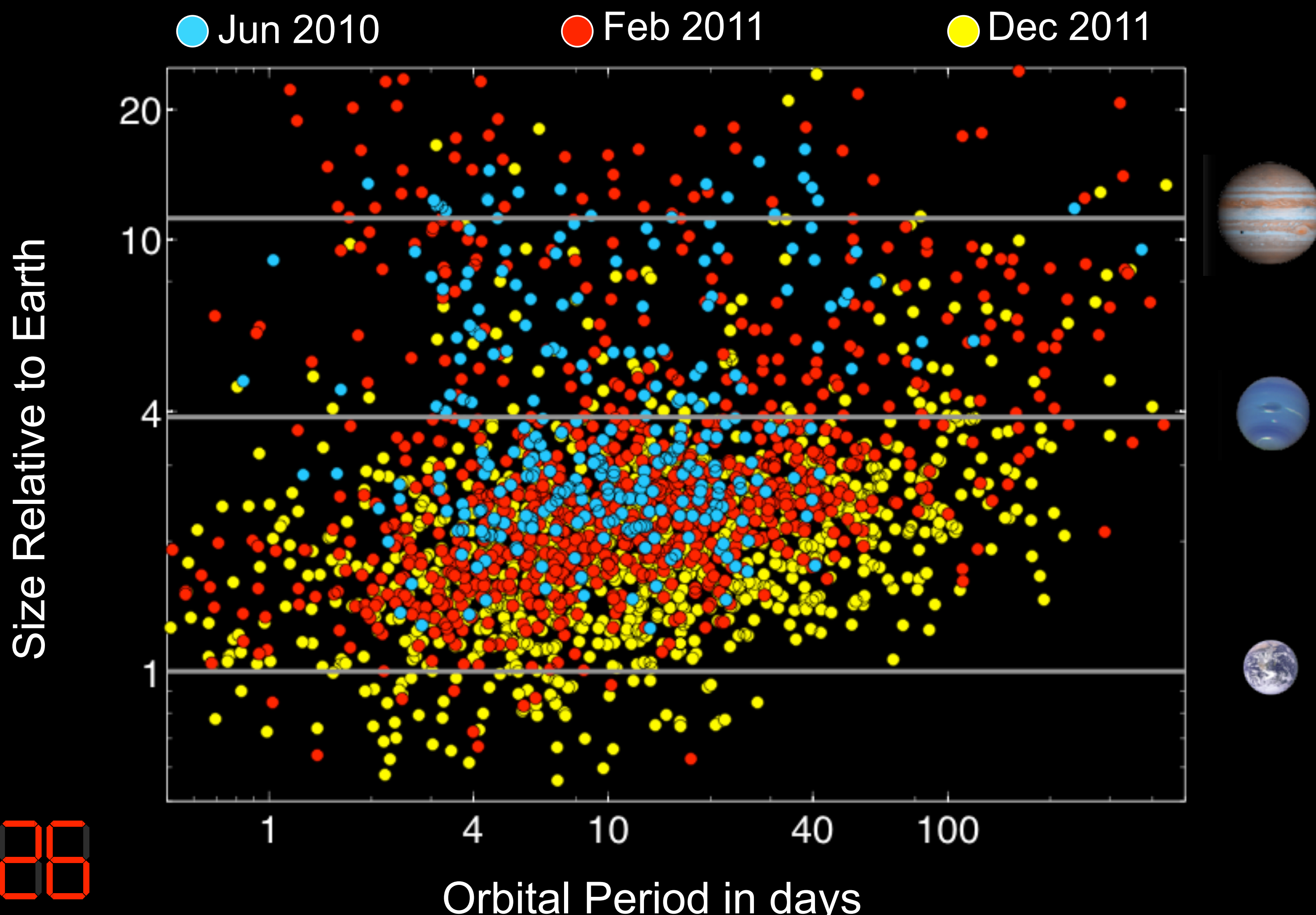
Q0-Q5: May 2009 - Jun 2010



1235

Candidates as of Dec 2011

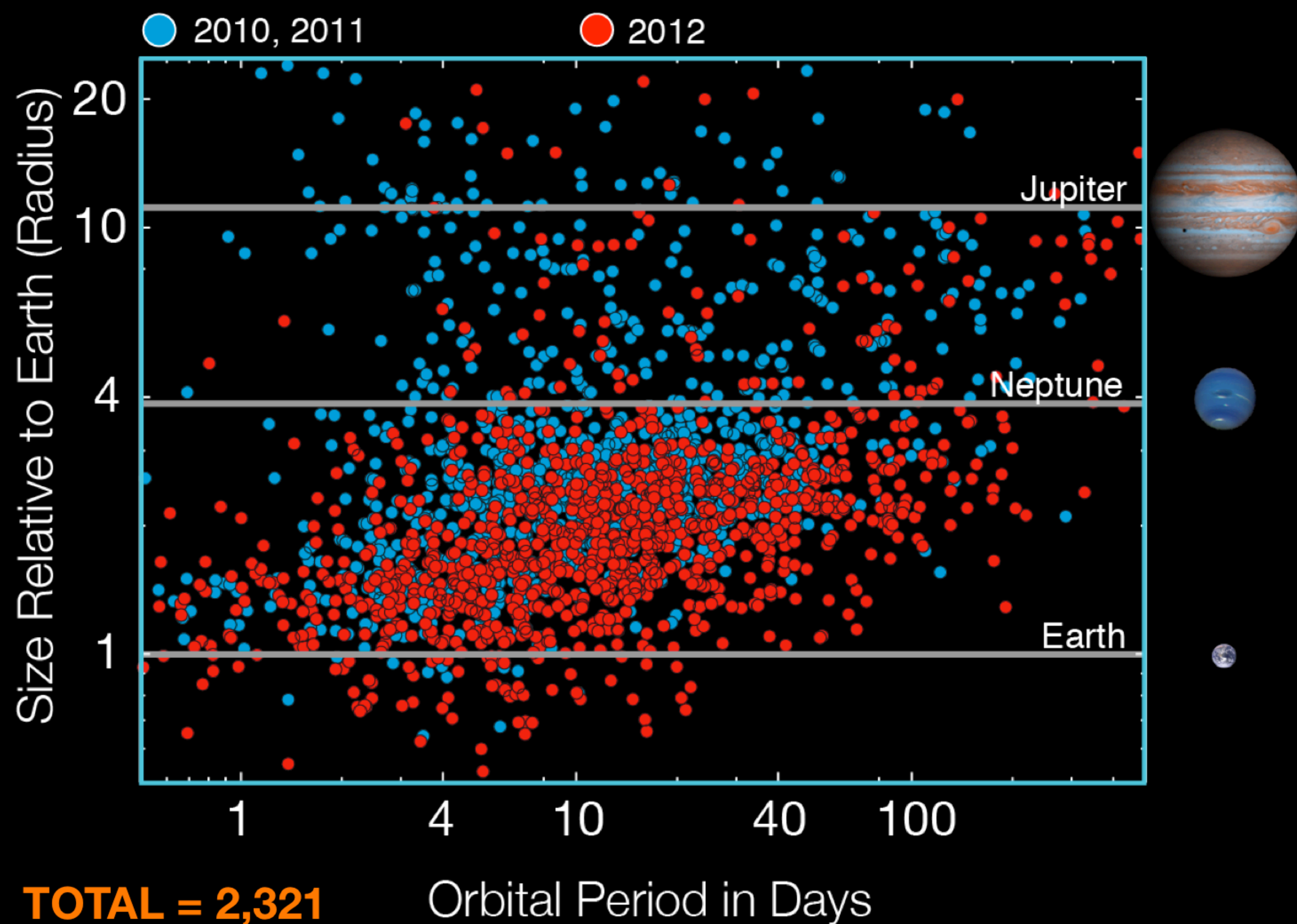
Q0-Q6: May 2009 - Sep 2010



2326

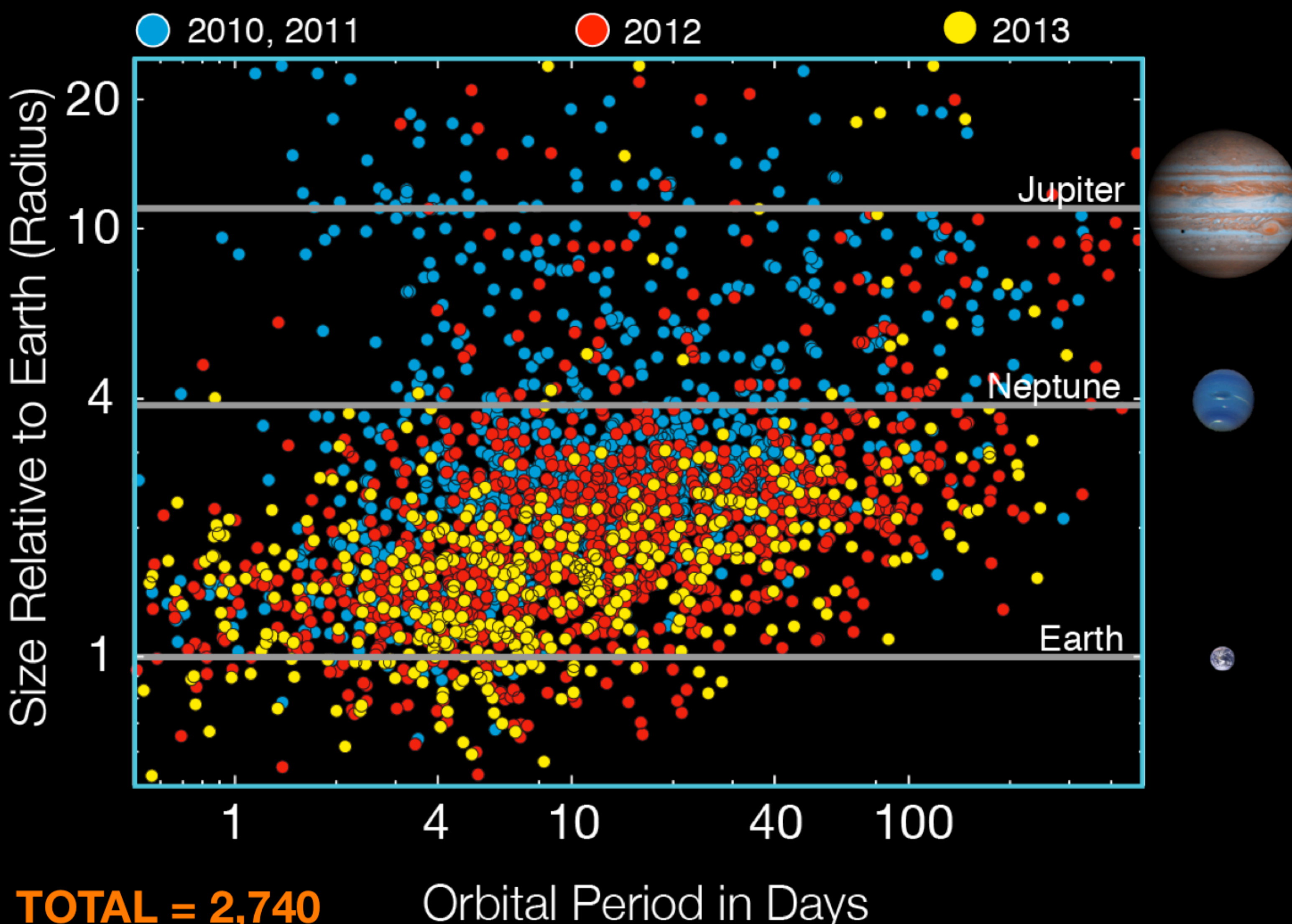
Planet Candidates

As of February 27, 2012



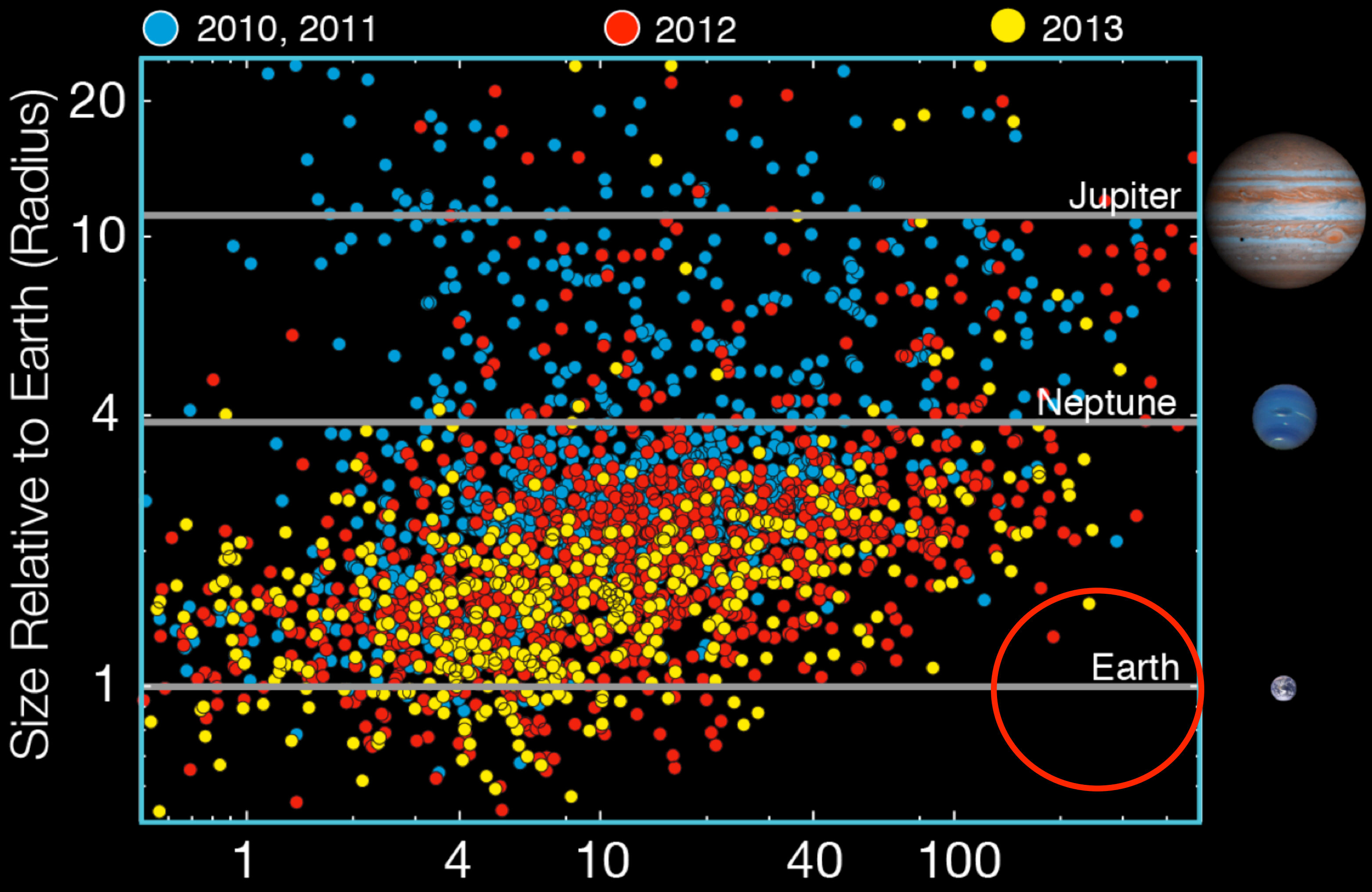
Planet Candidates

As of January 7, 2013



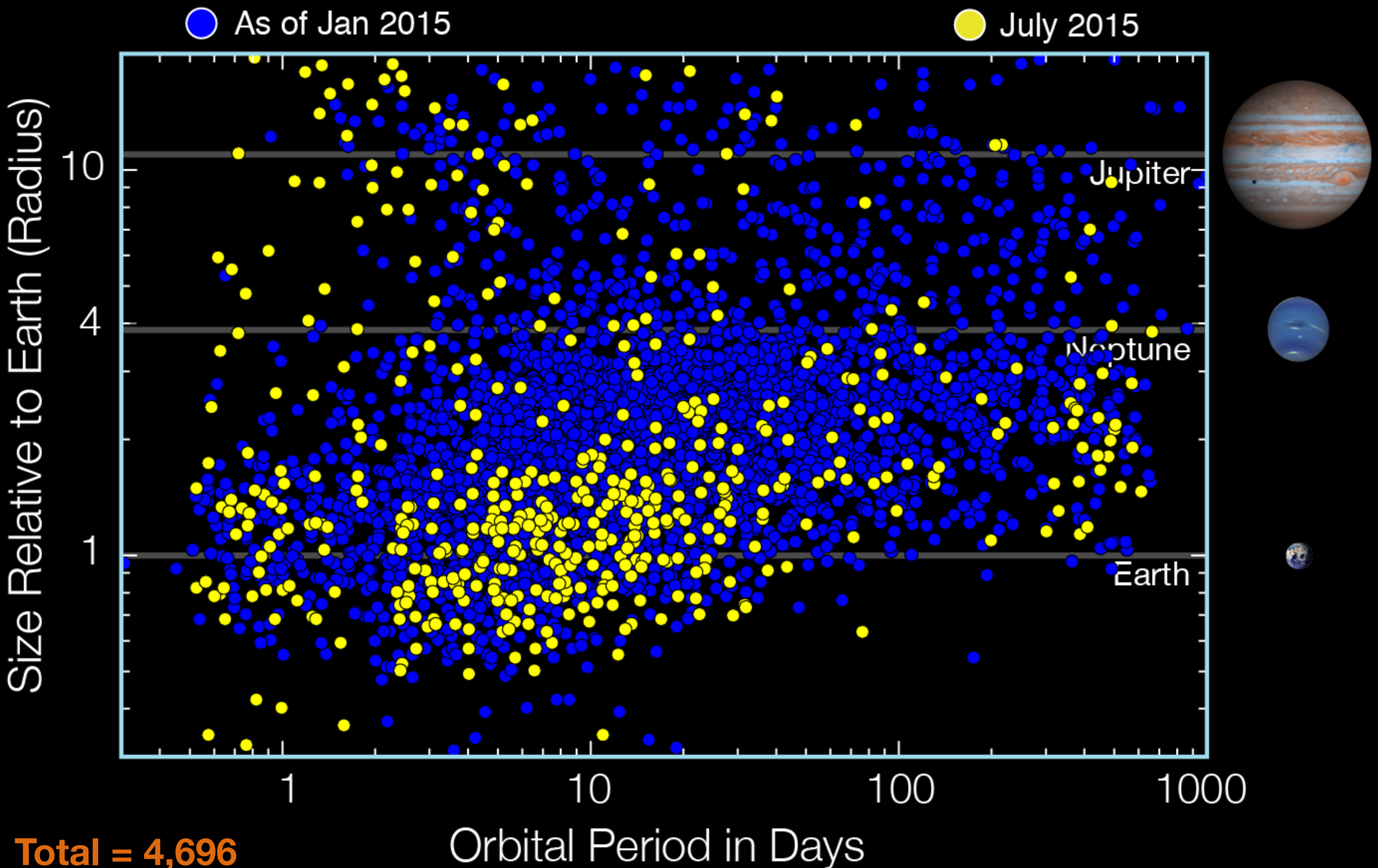
Planet Candidates

As of January 7, 2013



TOTAL = 2,740

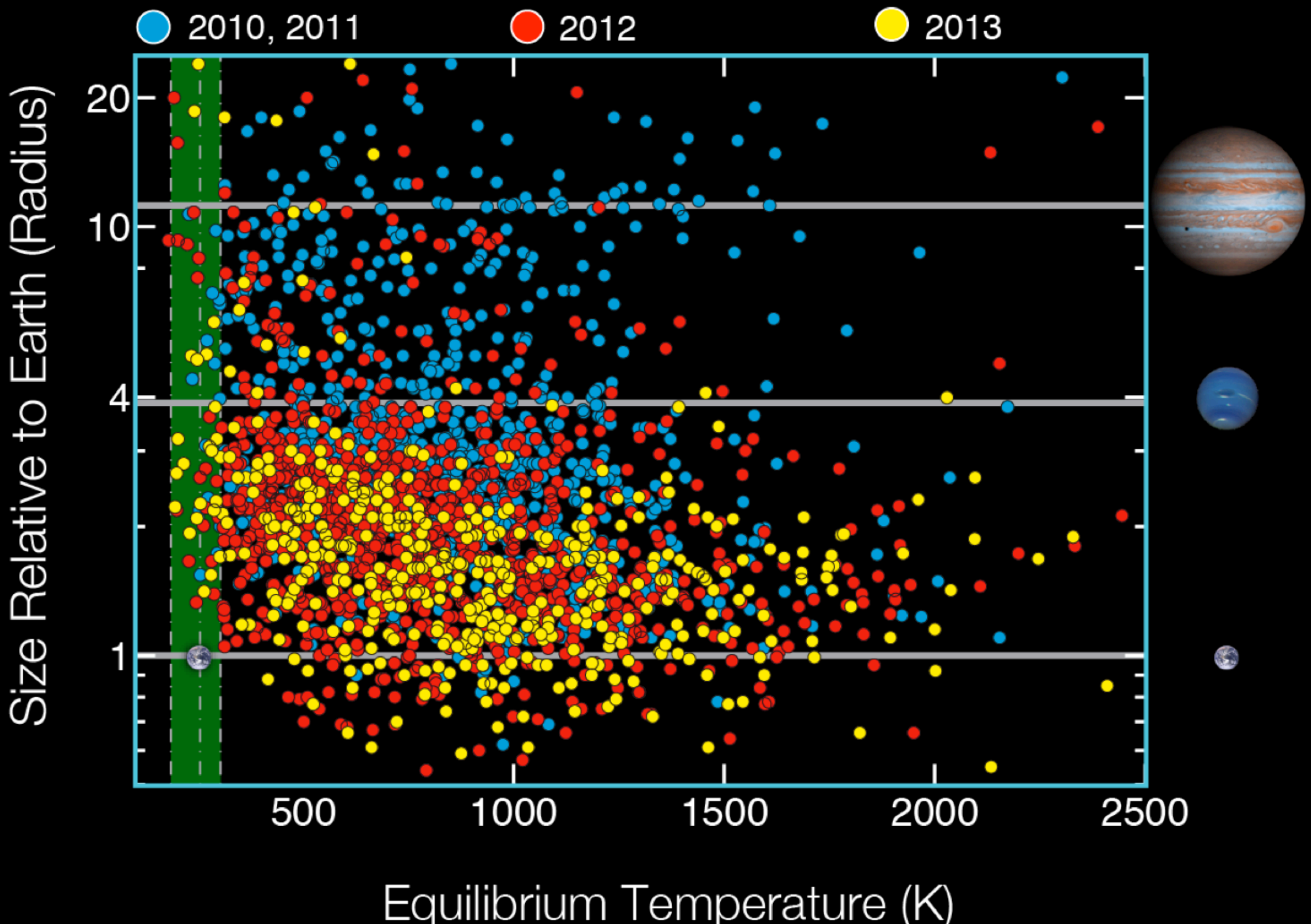
Kepler Planet Candidates



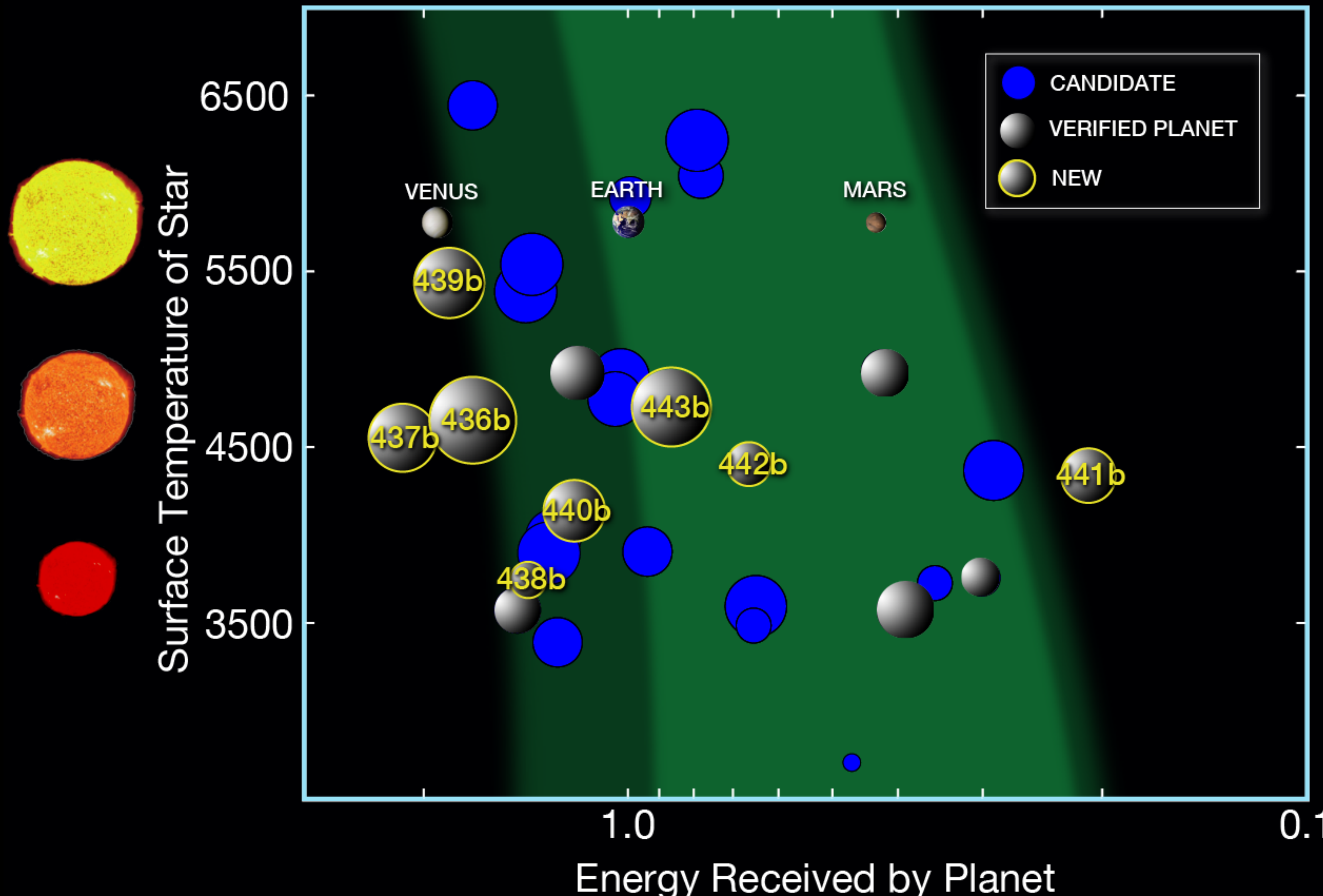
Total = 4,696

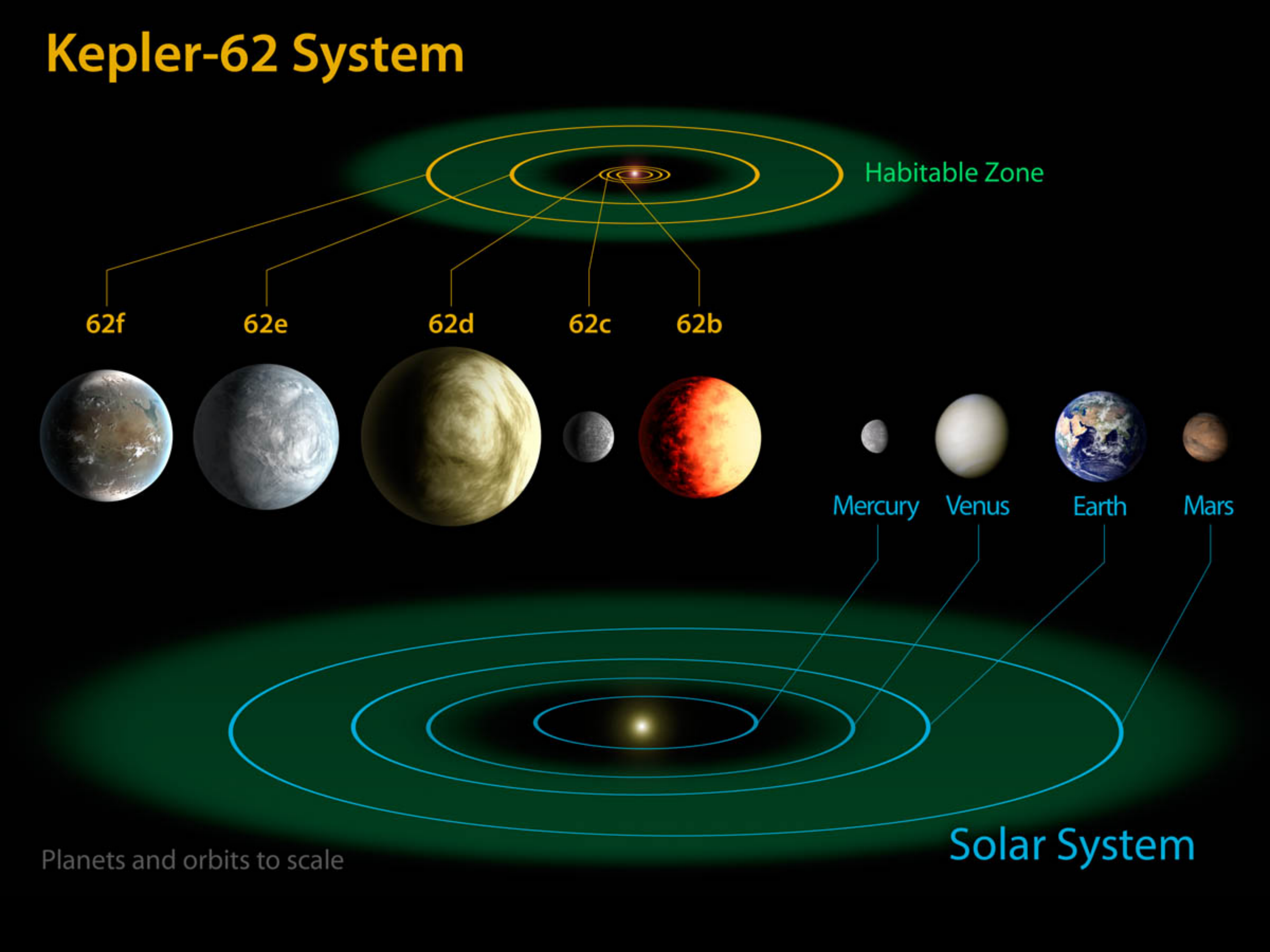
Candidates in the Habitable Zone

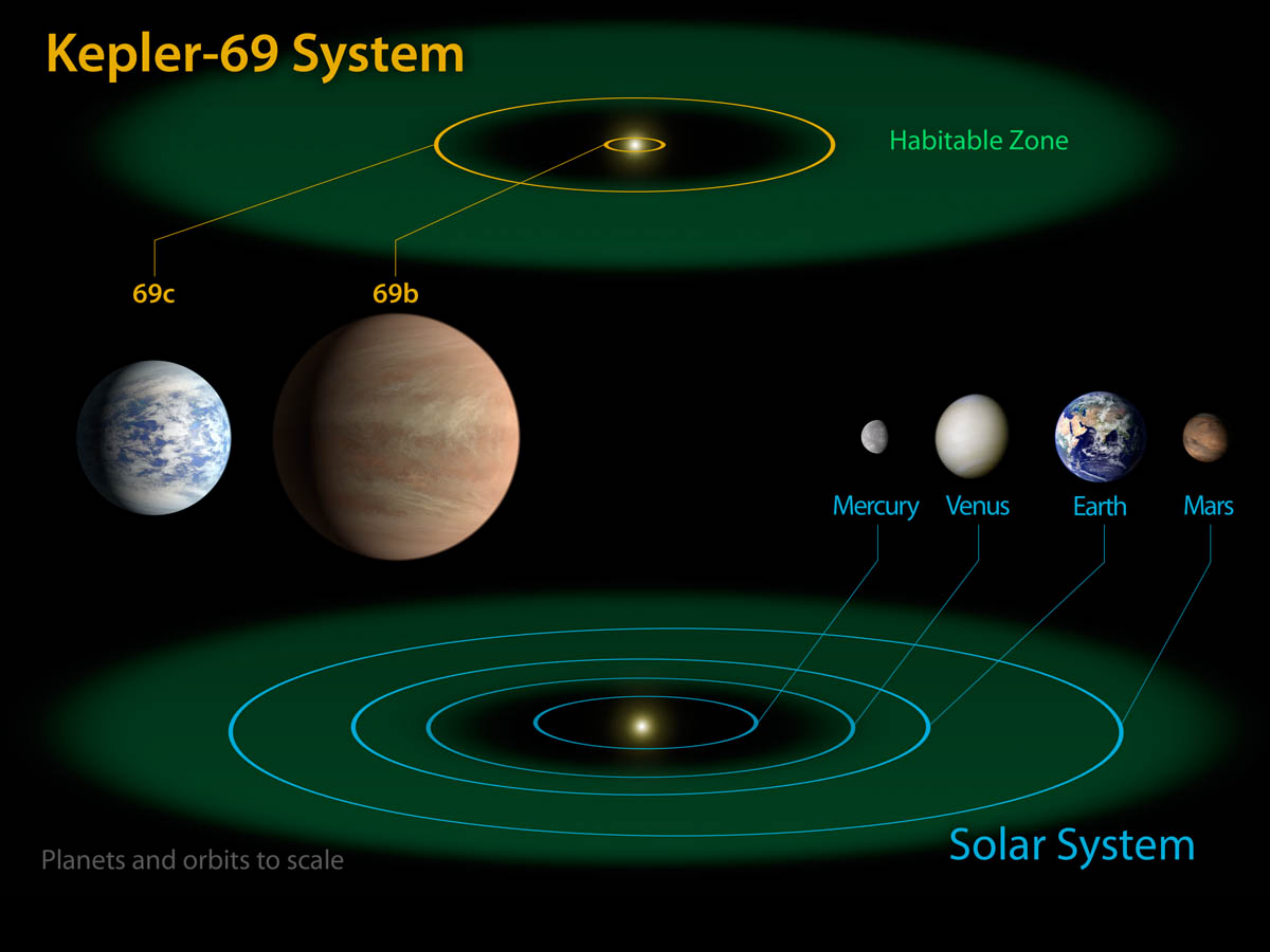
As of January 7, 2013



Habitable Zone Planets

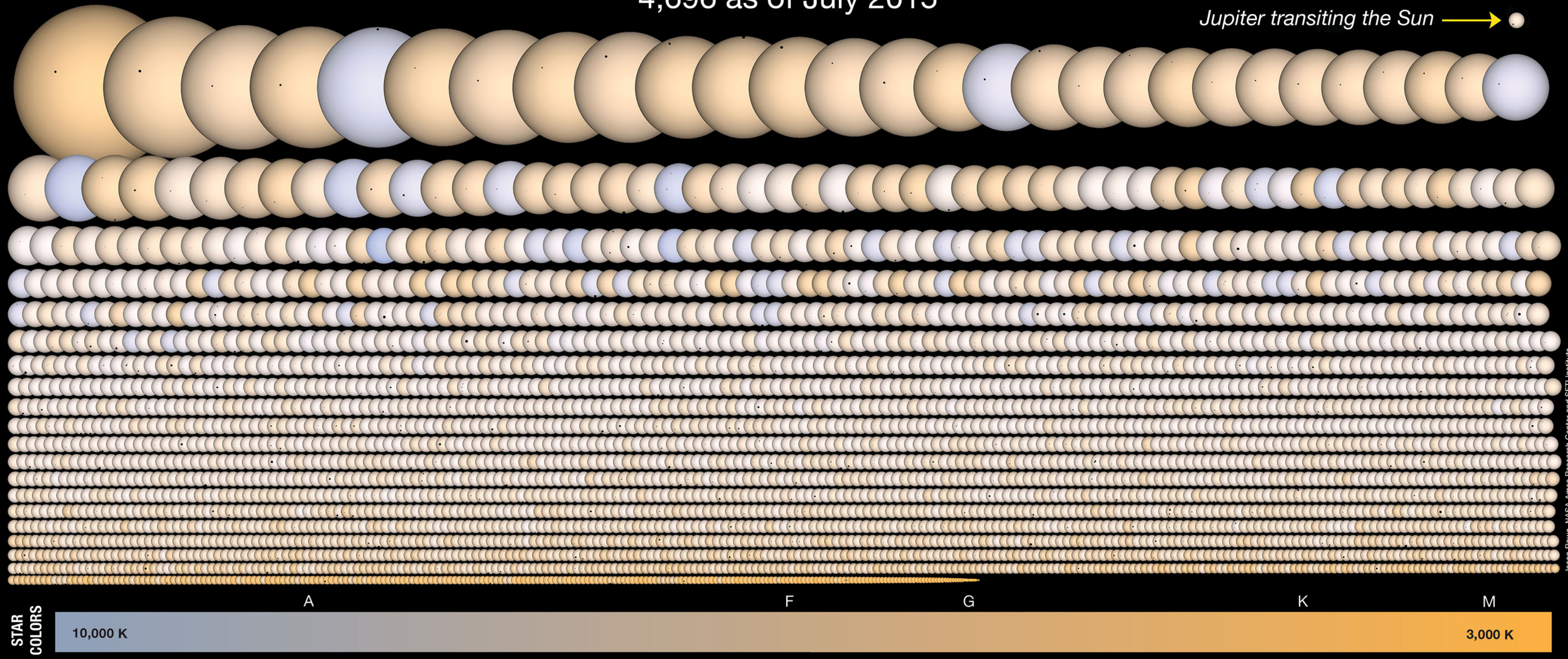



Kepler-62 System
Habitable Zone
62f
62e
62d
62c
62b
Mercury
Venus
Earth
Mars
Solar System
Planets and orbits to scale


Kepler-69 System
Habitable Zone
69c
69b
Mercury
Venus
Earth
Mars
Solar System
Planets and orbits to scale

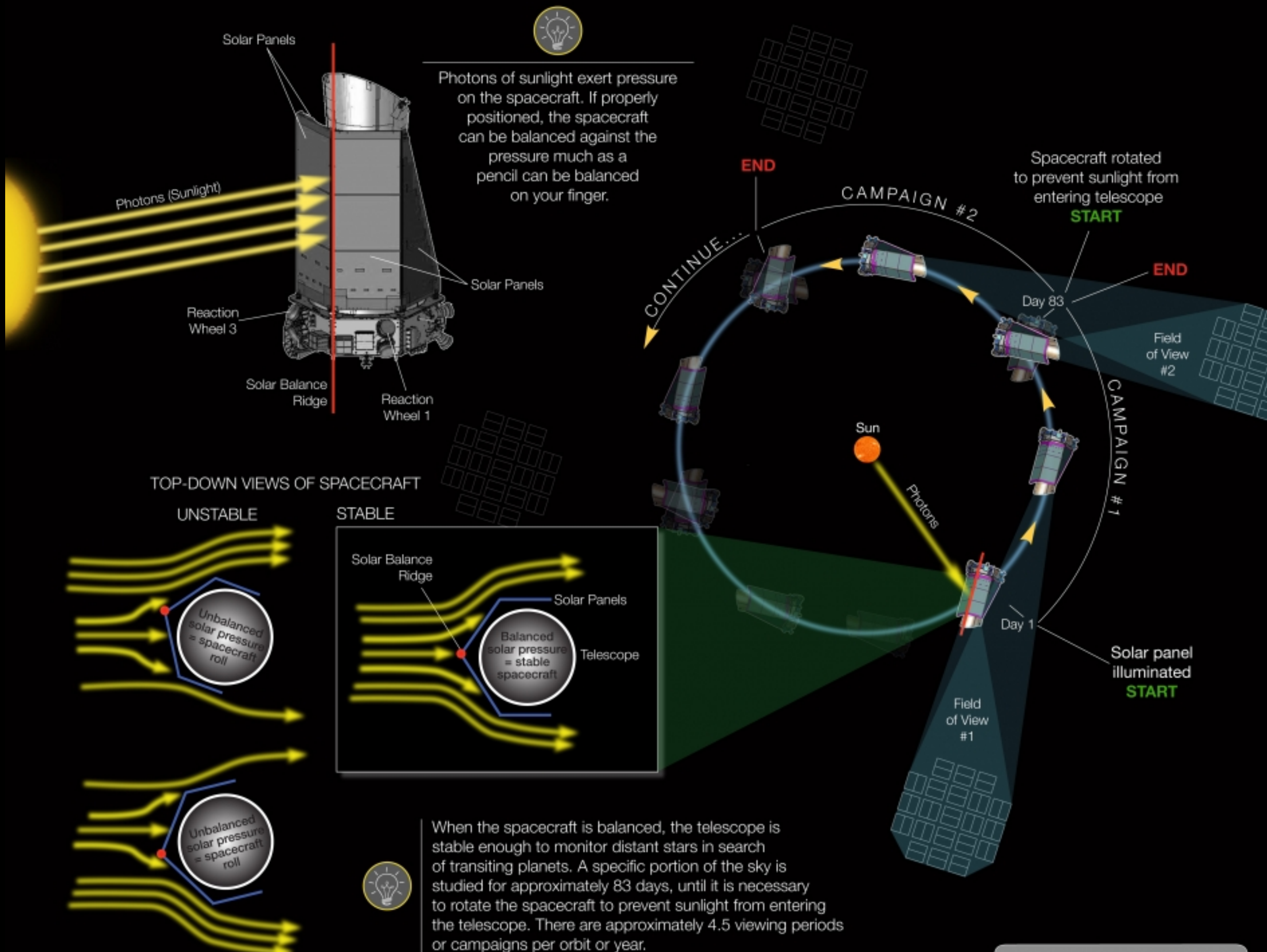
New Kepler Planet Candidates

4,696 as of July 2015



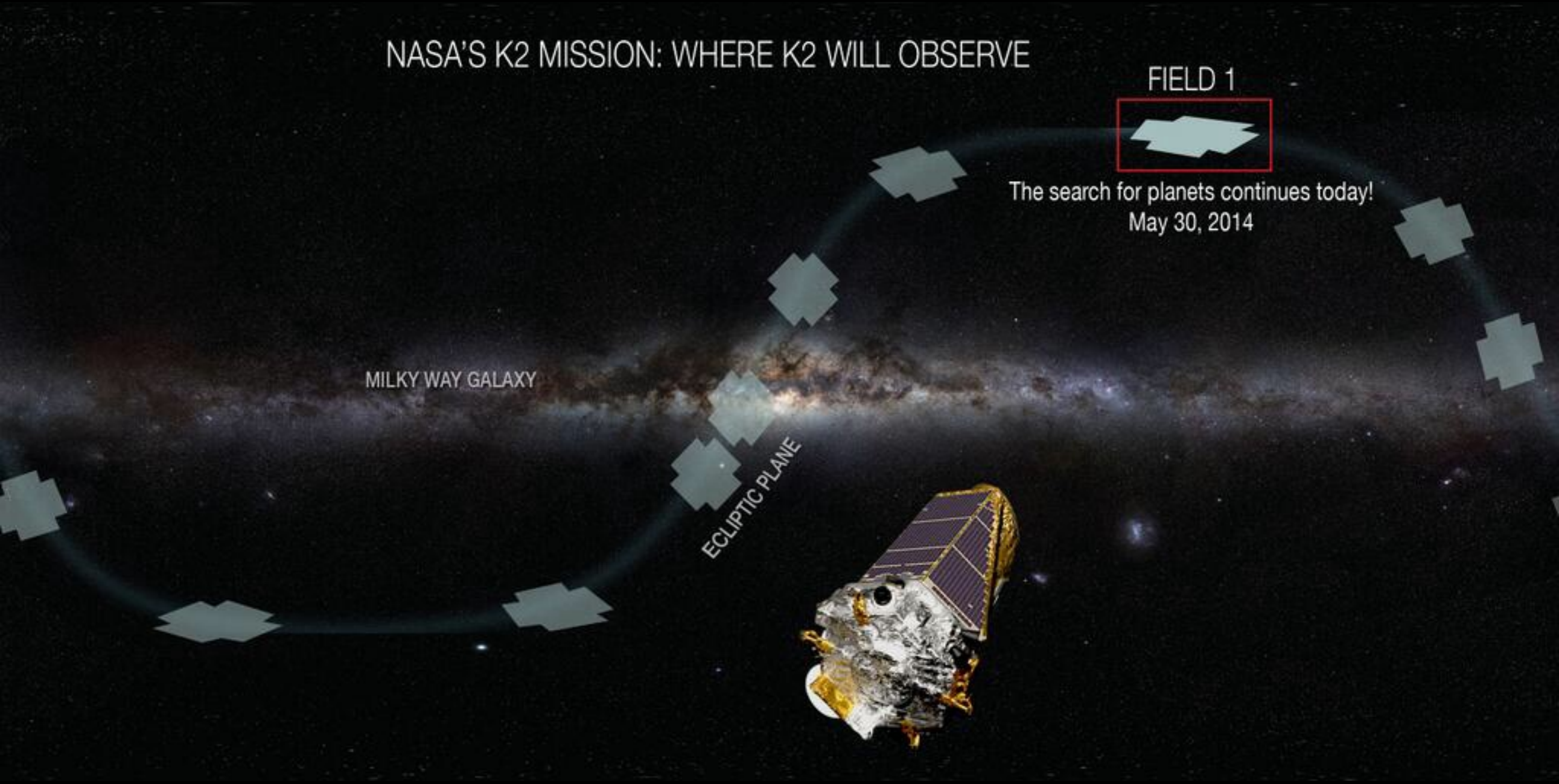
Kepler's Second Light: How K2 Will Work

Photons of sunlight exert pressure on the spacecraft. If properly positioned, the spacecraft can be balanced against the pressure much as a pencil can be balanced on your finger.



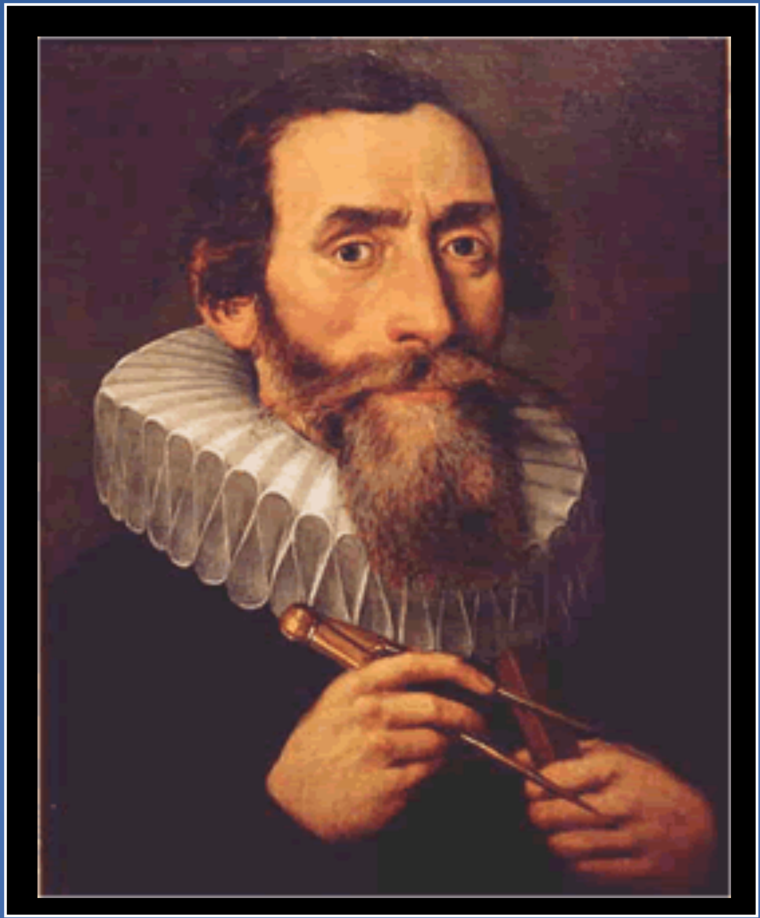
When the spacecraft is balanced, the telescope is stable enough to monitor distant stars in search of transiting planets. A specific portion of the sky is studied for approximately 83 days, until it is necessary to rotate the spacecraft to prevent sunlight from entering the telescope. There are approximately 4.5 viewing periods or campaigns per orbit or year.

CONCEPTUAL ILLUSTRATION OF SPACECRAFT SOLAR DISTURBANCE. THE ACTUAL DISTURBANCE IS DUE TO PHOTON PRESSURE, NOT SOLAR WIND.


NASA'S K2 MISSION: WHERE K2 WILL OBSERVE
FIELD 1
The search for planets continues today!
May 30, 2014
MILKY WAY GALAXY
ECLIPTIC PLANE


We seek
other worlds to better
understand our
place in the universe.

A Search for Habitable Planets



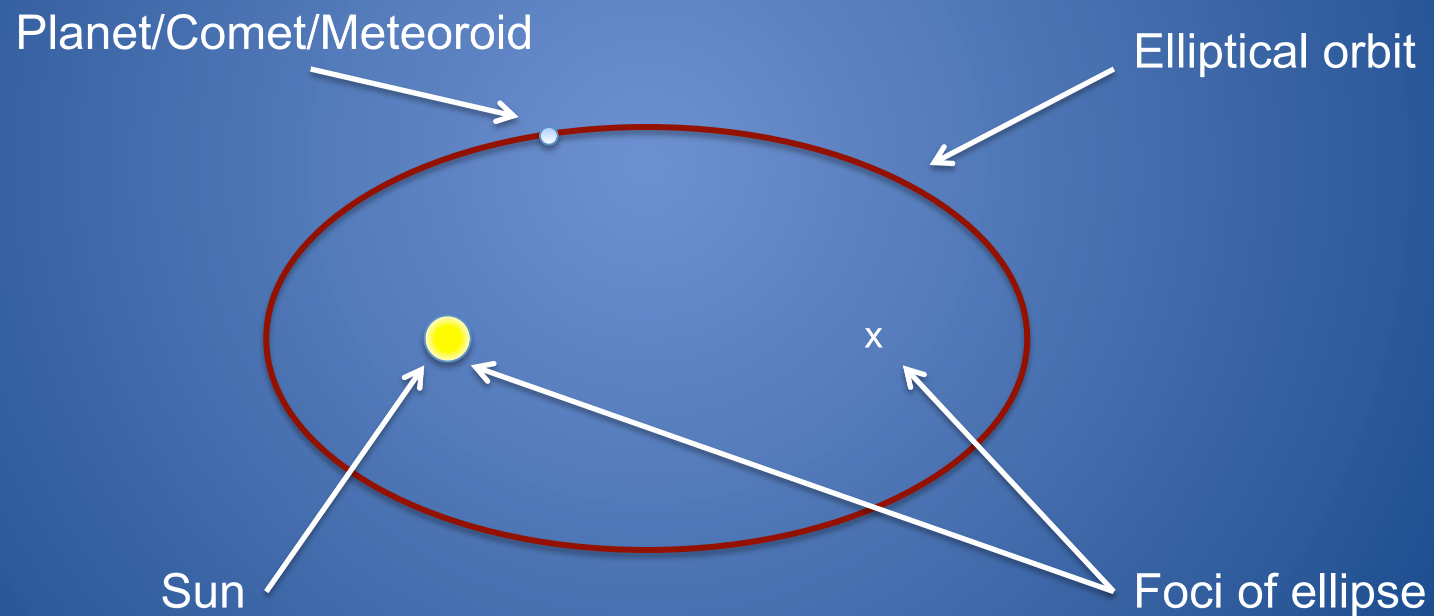
(By permission Sternwarte Kremsmünster)

A guy who's thought a lot about planets

More information: kepler.nasa.gov

Kepler's Laws of Planetary Motion

I. The orbit of every planet is an ellipse with the Sun at one of the two foci. (The other foci is empty.)

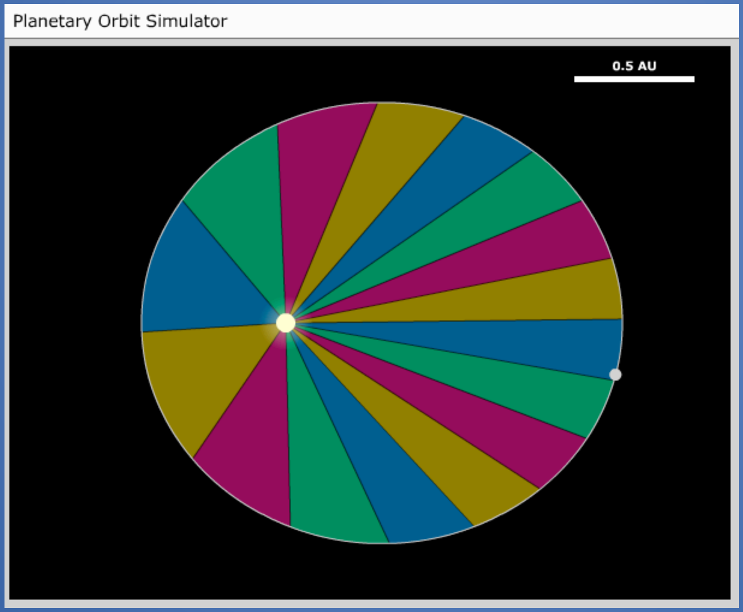


Note: This orbit is similar to the orbit of comets. Most planet's orbits would appear circular at this scale.

http://astro.unl.edu/classaction/animations/renaissance/kepler.html

Kepler's Laws of Planetary Motion

II. A line joining a planet and the Sun sweeps out equal areas during equal intervals of time.



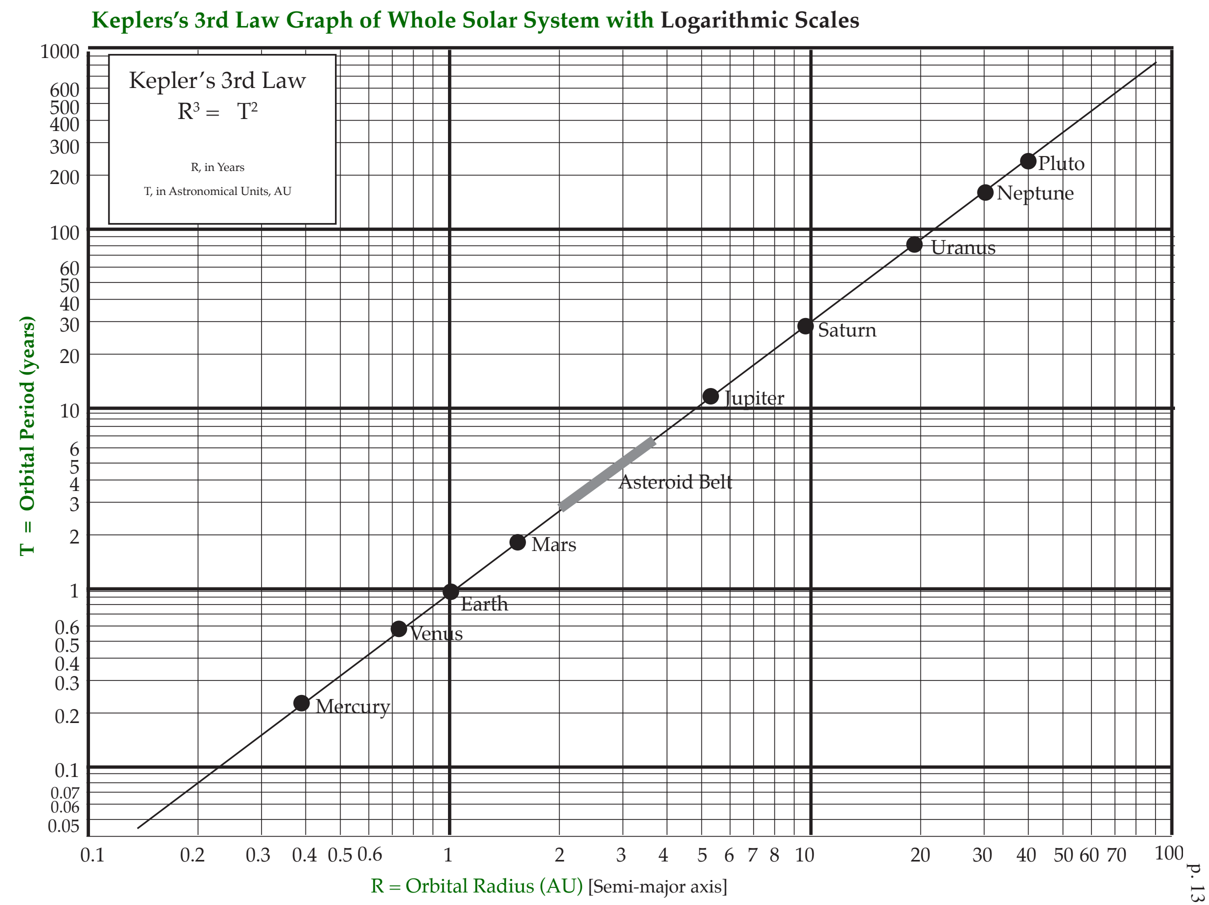
Orbit of Mercury marked in equal intervals of time using "Planetary Orbit Simulator."

http://astro.unl.edu/classaction/animations/renaissance/kepler.html

Kepler
A Search for Habitable Planets

Kepler's Laws of Planetary Motion

III. The square of the orbital period of a planet is directly proportional to the cube of the semi-major axis of its orbit.



Note: All objects -- planets, moons, asteroids, comets, meteoroids, dwarf planets -- all obey Kepler's 3rd Law.

A Search for Habitable Planets

Planet's Size: Deducing the Planet's Radius from Transit Data

$A_p/A_s = Z$

Converting to a percentage

$100\ (A_p/A_s) = Z\%$

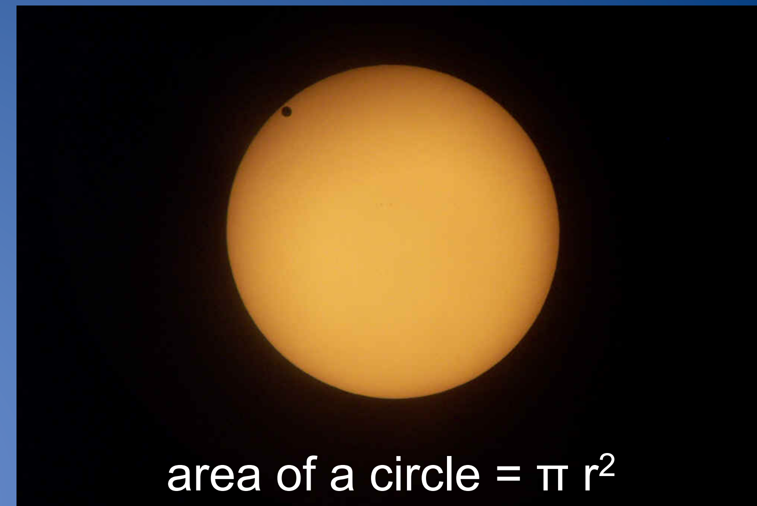
$100\ (\pi\, r_p^2 / \pi\, r_s^2) = Z\%$

$100\ (r_p^2 / r_s^2) = Z\%$

$r_p^2 / r_s^2 = Z\%/100$

$r_p^2 = r_s^2\,(Z\%/100)$

$r_p = r_s/10 \sqrt{Z\%}$



The Sun is about 100 times the radius of the Earth.

$r_{sun} \sim 100\ r_{earth}$

Substituting:

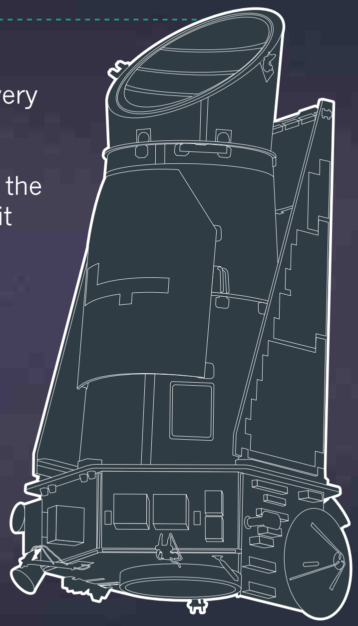
$r_p = 100\ r_{earth}/10\ (\sqrt{Z\%}\ )$

$r_p = 10\ r_{earth}\ (\sqrt{Z\%}\ )$

EXOPLANETS
THE NEXT 20 YEARS

Researchers have found nearly 2,000 worlds beyond our Solar System. Now they hope to understand them.

BY ALEXANDRA WITZE
DESIGN BY JASIEK KRZYSZTOFIAK

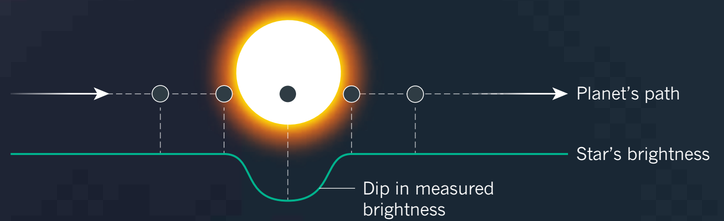


Twenty years ago this month, astronomers announced the discovery of 51 Pegasi b, the first confirmed planet orbiting a Sun-like star. The hellish gas giant orbits just beyond the searing heat of its parent star, and it opened astronomers' eyes to the astonishing range of alien worlds that exist throughout the Galaxy.

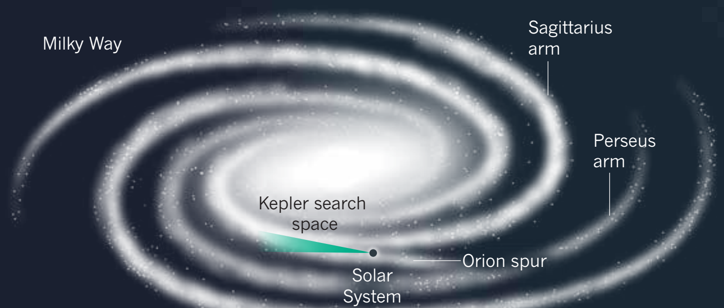
The tally of known extrasolar planets now stands at 1,978, with nearly 4,700 more candidates waiting to be confirmed. On 29 November, exoplanet researchers will gather in Hawaii to review these extreme solar systems — and map out a path for the next two decades.

The search so far

By far the greatest haul of exoplanets has come from NASA's Kepler spacecraft (pictured above), which for four years stared at a small patch of the night sky in search of stars that dim temporarily as planets cross their faces. The main Kepler mission ended in 2013, but planet hunting continues in a revamped 'K2' mission.

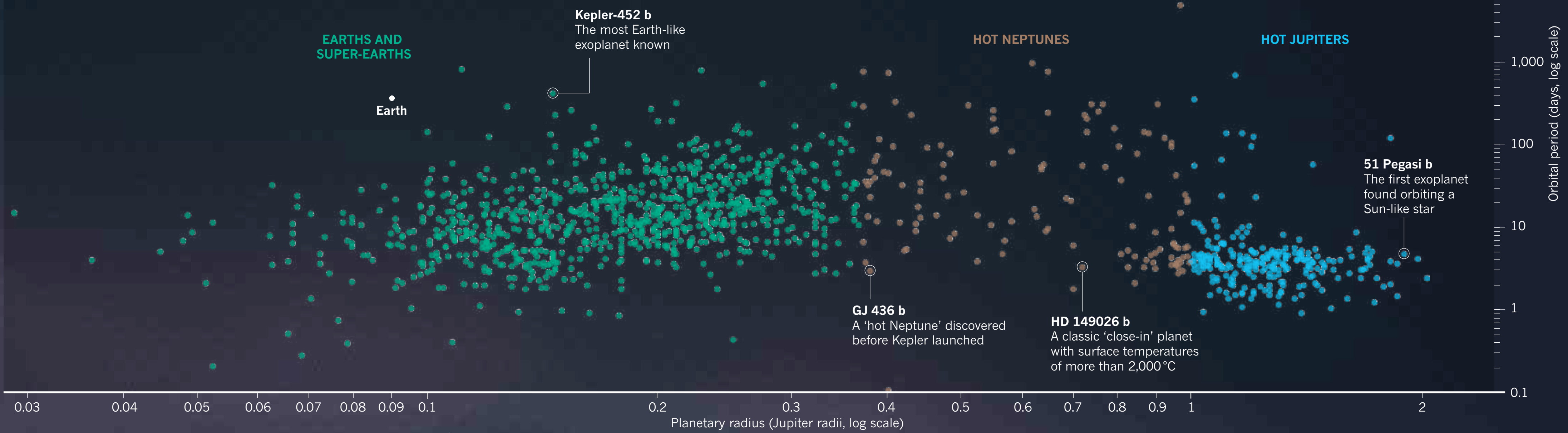


Kepler's field of view covers only about 1/400 of the night sky.



THE WORLDS WE KNOW

Many of the exoplanets discovered to date are startlingly different from the worlds in the eight-planet architecture of our Solar System. They range from bloated gas balls close to their stars to ice worlds looping far beyond — and in between is a handful of Earth-like planets in the 'Goldilocks zone', where conditions are just right for life as scientists know it.



THE NEXT FRONTIER

Astronomers now have to figure out what to do with this bonanza of planet discoveries. The research goals for the next two decades include gathering data on what the planets actually look like, from the clouds in their atmospheres to the conditions on their surfaces.

What's next?

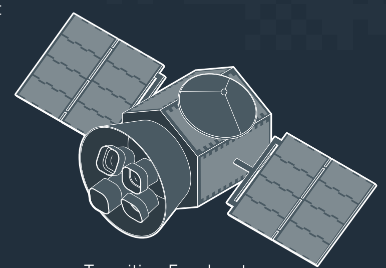
GEMINI PLANET IMAGER
This mission is teasing out the heat of planets from that of their host stars, allowing direct measurements of characteristics such as mass, temperature and atmospheric composition.

NEXT-GENERATION TRANSIT SURVEY
An ongoing project to search for exoplanets in Southern Hemisphere skies.

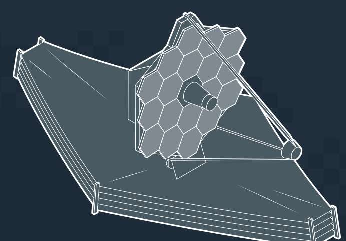
TRANSITING EXOPLANET SURVEY SATELLITE
The spacecraft, set to launch in 2017, will search for rocky worlds around nearby bright stars. Astronomers can then follow up the finds using ground-based telescopes.

JAMES WEBB SPACE TELESCOPE
Targeted for a 2018 launch, the telescope will measure planetary atmospheres in infrared wavelengths to probe their chemical compositions.

PLATO
The space observatory, set to begin operating in 2024, will search for Earth-like worlds in the habitable zones of up to 1 million stars.



Transiting Exoplanet Survey Satellite



James Webb Space Telescope

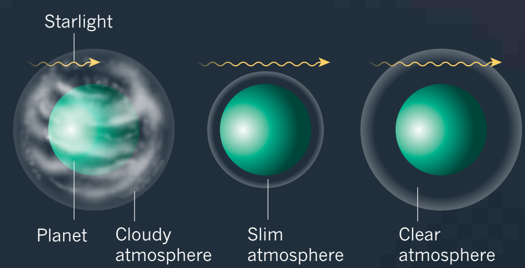
DATA FOR PLANETS SCATTERPLOT: EXOPLANET.EU; KEPLER PICTURE: REDRAWN FROM NASA IMAGE

How many are there?

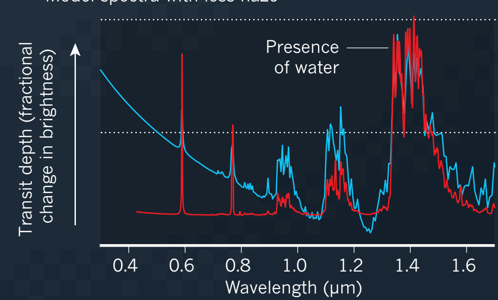
Untold numbers of exoplanets remain undiscovered, but astronomers are starting to get a better handle on the fraction of Earth-sized planets that might contain liquid water. The most common stars in the Galaxy are M dwarfs, which are smaller and cooler than the Sun; scientists estimate that there is up to one Earth-sized planet for every two M dwarfs. A fraction of those planets might be habitable.

What do they look like?

The newest frontier is probing exoplanet atmospheres, looking at what changes as a planet slips on and off the face of its star (as seen from Earth).



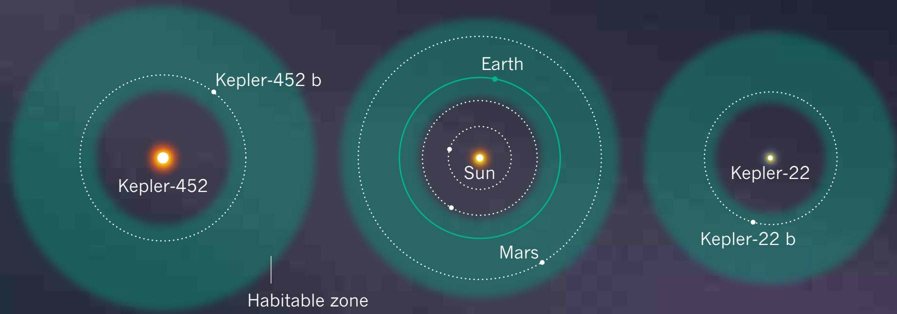
Chemical analyses of how the starlight is absorbed reveals compounds such as water in the cloudy skies of distant exoplanets.



SPECTRA: D. DEMING ET AL. ASTROPHYS. J. 774, 95–112 (2013), CC-BY-3.0.
HABITABILITY PLOT: R. BARNES, V. S. MEADOWS & N. EVANS ASTROPHYS. J. (IN THE PRESS); PREPRINT AT HTTP://ARXIV.ORG/ABS/1509.08922

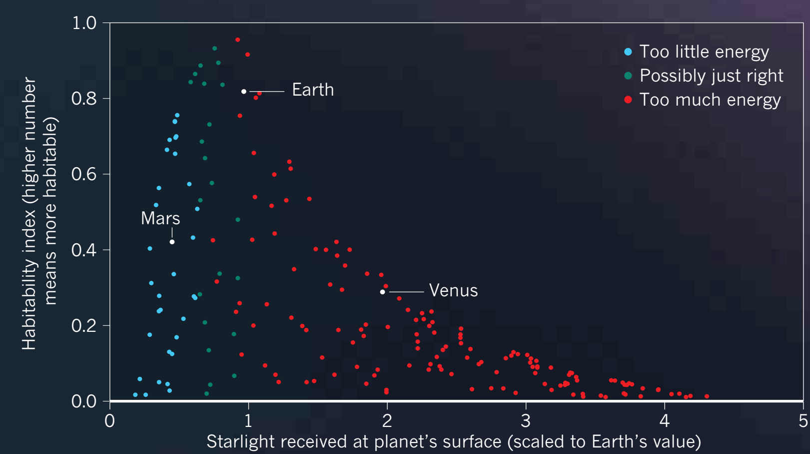
Are they habitable?

The most intriguing planets lie in the habitable zones of their stars, where temperatures allow liquid water to exist on the planet's surface. The placement and width of the habitable zone varies depending on how bright the host star is; the dimmer the star, the closer the planet must be to lie in the habitable zone.



So, is there life?

Maybe. Now the question is how to decide which of the potentially thousands of exoplanets to pursue further. Researchers recently devised a 'habitability index' that shows which planets are most likely to have liquid water on their surface. The index can be compared against other measures — such as the amount of starlight received by the planet — to explore which planets might be worth targeting first for searches for extraterrestrial life.



Teaching Mineral Resources with an Emphasis on the NGSS Practices and Crosscutting Concepts – Aida Awad (Maine East High School), Susan M. Sullivan (University of Colorado), and Edward Robeck (AGI)

Teaching Mineral Resources with an Emphasis on the NGSS Practices & Crosscutting Concepts

Aida Awad, Maine East High School, NAGT Past President
Ed Robeck, American Geosciences Institute, Director Center for Geoscience & Society
Alex Speer, Executive Director, Mineralogical Society of America
Susan Sullivan, Coop. Inst. for Research in Enviro. Sciences, NAGT Past President

Center for Geoscience & Society
american geosciences institute

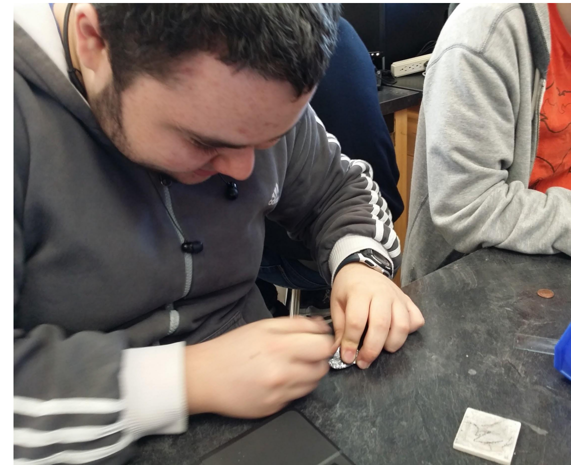
InTeGrate
Interdisciplinary Teaching about Earth for a Sustainable Future

CIRES

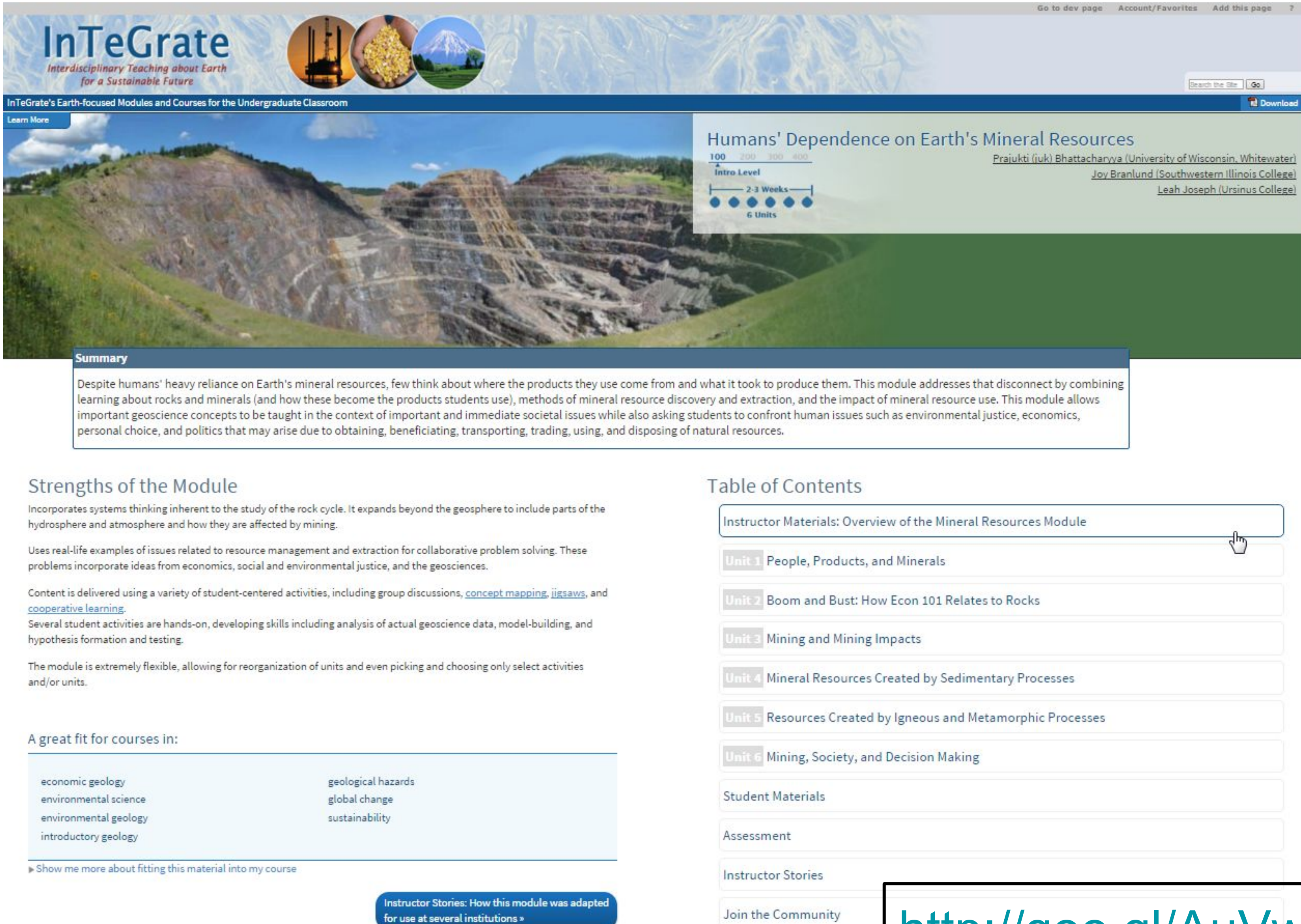
Mineralogical Society of America · Mineralogy · Petrology · Crystallography · 1916 2016 · American Mineralogist Centennial

learning goals of this workshop:

- ➢ I can adapt InTeGrate module materials to align with NGSS crosscutting concepts, practices and DCIs.
- ➢ I can explain how and why managing mineral resources is a global challenge that depends both on geological (mineral forming) processes and non-geological factors with various impacts on the environment and communities.



InTeGrate website:



http://goo.gl/AuVwy6

spreadsheet access to materials:

Humans' dependence on mineral resources

Unit	activity	link to Google doc version	description	practice / crosscutting concept alignment
pre / overarching				
	concept map	https://docs.google.com/document/d/1AU1G7Y_oK34nq0D-HjbzY38p-xl6hQfyf7uQsSKRYUs/edit	students/groups choose a mineral resource to track their learning throughout the entire module adding new nodes to the concept map as they progress	
	concept map rubric	https://docs.google.com/document/d/1iGlqHwg_HLg32qF--ekt0KLOsixr2H4WuVohh4cJ4-M/edit	grading rubric for the concept map - should be shared with students at the start of the module when assigning the concept map	
	InTeGrate page	http://serc.carleton.edu/integrate/teaching_materials/mineral_resources/assessment.html	this page contains useful links to information on using concept maps and a sample concept map	
unit 1	pre-class readings & prep	https://docs.google.com/presentation/d/1FslWhNNPkhuFA19Mrc1bEWC_zdEMbldmKrOF3E3Nzx8/edit#slide=id.p11	define minerals & mineral resources, explore mineral physical properties from the viewpoint of how they are useful	practices: analyzing & interpreting data, obtaining information CCC: structure & function
	mineral sample & mineral use matching activity	https://docs.google.com/document/d/1pi870eF3rmE3dGy9LuRfiZ3wnrtVJ1x4qxMM2VkRco8/edit	students match mineral hand specimens or images with products they use in pictures or samples	practices: analyzing & interpreting data, obtaining information CCC: structure & function
	teacher guide for matching activity	https://docs.google.com/document/d/1MXJrmmtMu1DipxEbdb8GHpr0J0Pa1dx1jsnxOxpZPUQ/edit	teacher guide to products for matching activity	
	Economic development & resouce use	https://docs.google.com/presentation/d/1C8j6Q5FpNjNFQifYuzMFNQE4HYGArK3bQEzq09SyqPw/edit#slide=id.p4	slides for economic development & resource use	
	Economic development & resouce use	https://docs.google.com/document/d/1iYRxKtXhhyiraVphaxa1C1yRn5txGwz_GP9uPgz420c/edit	student doc: students begin to explore the relationships between economic development (global), resource use, and resource extraction, the activity strongly supports interpretation of graphical data	practices: asking questions & defining problems, developing and using models, analyzing and interpreting data, computational thinking, engaging in argument from evidence, obtaining, evaluating and communciating information CCC: patterns, scale, proportion, quantity
	in-class or homework post-class [illegible]	http://www.ted.com/talks/hans_rosling_on_global_pop[illegible]	video: Hans Rosling TED talk Global popoulation Growth, Box by Box - the video accompanies a set of questions for students to [illegible]	

pre & unit 1 | unit 2 | unit 3 | unit 4 | unit 5 | unit 6 | practices & CCCs

https://goo.gl/SuLpHq

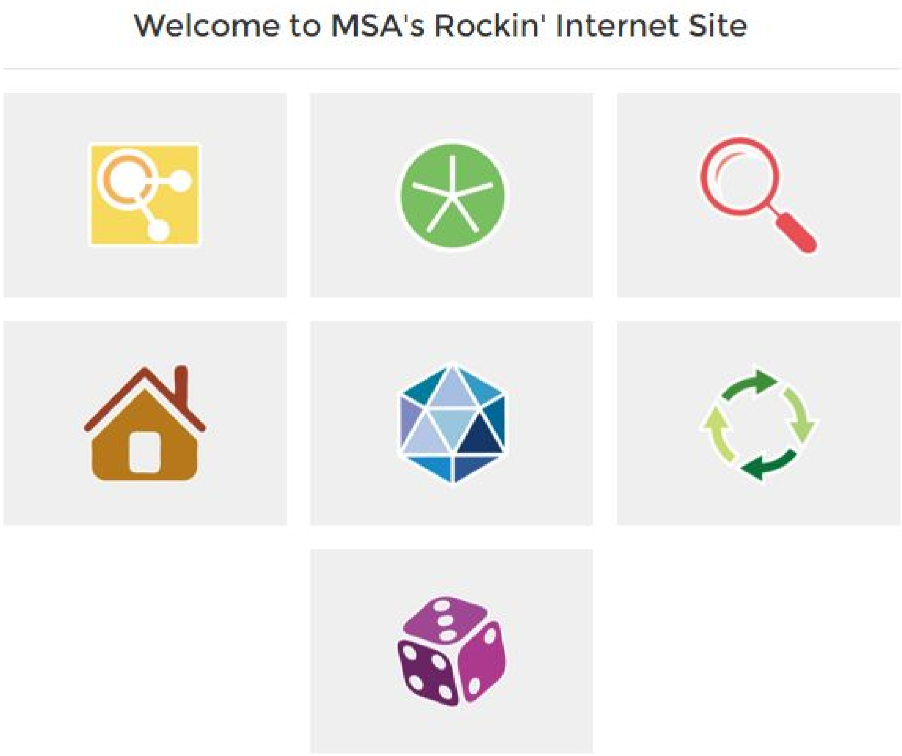
Related AGI Education Resources To Explore

american geosciences institute
connecting earth, science, and people

	Earth Science Week Discover the resources offered through this international event, organized by AGI each October to promote better understanding and appreciation of Earth science and encourage stewardship of the planet. http://www.earthsciweek.org/classroom-activities
	**Big Ideas in Earth Science** Big Ideas videos bring to life the "big ideas" of Earth science—the nine core concepts that everyone should know. Teachers can use the videos in many ways. http://www.earthsciweek.org/big-ideas
	Center for Geoscience and Society Education Resource Network – The geoscience education resources on this site come from a variety of providers. The site provides visitors with the widest possible collection of curricula, classroom activities, teacher professional development opportunities, science education standards, virtual field trips, teaching ancillaries, and much more. http://geocntr.org/education-resources/ Critical Issues Program The Critical Issues Program provides a portal to decision-relevant, impartial, expert information from across the geosciences. http://www.americangeosciences.org/critical-issues
	K-5 Geosource If you are involved in elementary science education in any way, this Web site is for you. The site has a rich store of content, activities, services and links for you to explore, but this is only the beginning. http://www.k5geosource.org/index.html

Mineralogical Society of America resources:

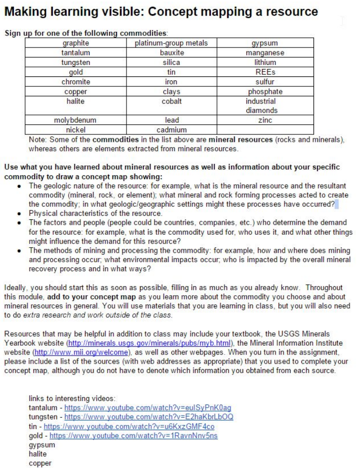
Mineralogy 4 Kids
Mineralogy 4 Kids is the educational outreach website for the Mineralogical Socieety of America (MSA). This interactive website is designed to help children of all ages learn about mineral groups, properties, and identification. Visitors to the site can also learn about the rock cycle, crystals, and minerals used in homes. Additional resources are also listed.



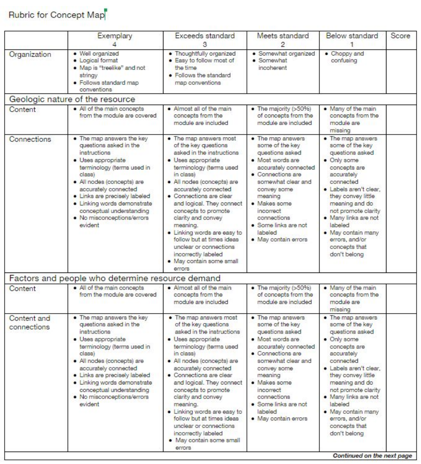
Mineral Identification: MSA Mineral Collector's Corner
The Mineralogical Society of America provides an online Mineral Identification Key to help users recognize the attributes of many kinds of minerals. the site gives information about mineral properties, environments, and associations. The Mineral Identification Key website is primarily focused on the needs of collectors, including a description of how basic mineral identification kits can be assembled.

links to Google Docs versions of activities:

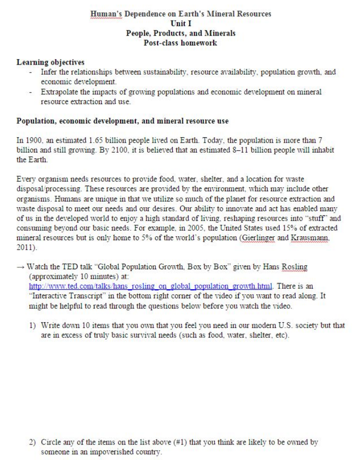
https://goo.gl/PQffq0
Concept mapping a resource



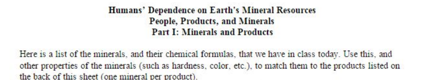
https://goo.gl/9JDDri
Concept map rubric



https://goo.gl/wVyDVR
People, products & minerals



https://goo.gl/44FR9p
Minerals & Products

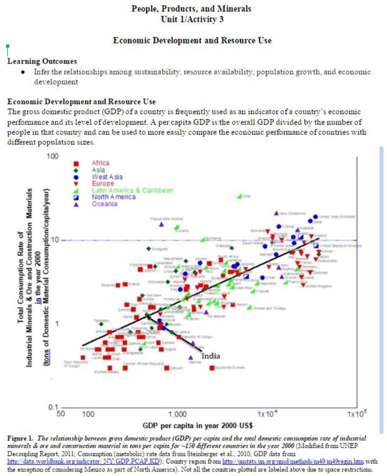


Humans' Dependence on Earth's Mineral Resources
People, Products, and Minerals
Part I: Minerals and Products

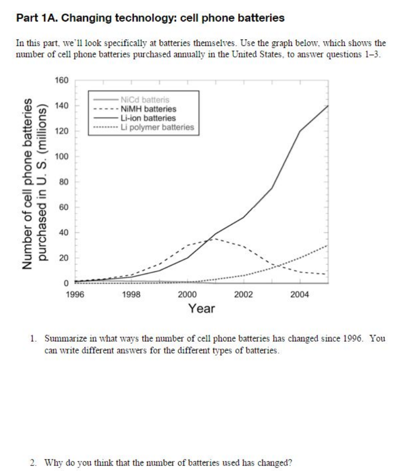
Here is a list of the minerals, and their chemical formulas, that we have in class today. Use this, and other properties of the minerals (such as hardness, color, etc.), to match them to the products listed on the back of this sheet (one mineral per product).

Mineral Name	Chemical Formula
Apatite	$Ca_5(PO_4)_3(F,Cl,OH)$
Bauxite	$Al(OH)_3$ - $AlO \cdot OH$
Barite	$BaSO_4$
Calcite	$CaCO_3$
Chalcopyrite	$CuFeS_2$
Galena	PbS
Graphite	C
Gypsum	$CaSO_4 \cdot 2(H_2O)$
Halite	NaCl
Hematite (red)	Fe_2O_3
Hematite (specularite)	Fe_2O_3
Kaolinite	$Al_2Si_2O_5(OH)_4$
Muscovite	$KAl_2(AlSi_3)O_{10}(OH,F)_2$
Quartz	SiO_2
Talc	$Mg_3Si_4O_{10}(OH)_2$

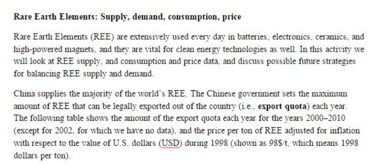
https://goo.gl/Hbj24R
Economic development & resource use



https://goo.gl/vLwoiH
Rechargeable batteries & mineral resource use



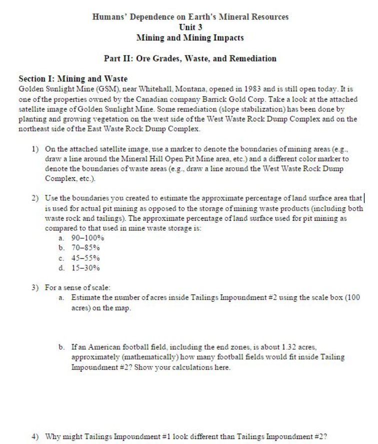
https://goo.gl/I5y8VS
Rare earth elements



Rare Earth Elements: Supply, demand, consumption, price

Year	Total export quota (metric tons)*	REE price per ton** in USD during 1998, expressed as (98$/t)
2000	47,000	6,110
2001	45,000	5,330
2002	N/A	6,800
2003	40,000	5,450
2004	45,000	7,410
2005	65,580	5,500
2006	61,070	3,150
2007	59,643	4,160
2008	49,990	10,300
2009	48,155	7,100
2010	30,258	14,500

https://goo.gl/5bh78j
Ore grades, waste, and remediation



AGU GIFT Workshop 2015: Human Dependence on Earth's Mineral Resources Activities

Making learning visible: Concept mapping a resource

Sign up for one of the following commodities:

graphite	platinum-group metals	gypsum
tantalum	bauxite	manganese
tungsten	silica	lithium
gold	tin	REEs
chromite	iron	sulfur
copper	clays	phosphate
halite	cobalt	industrial diamonds
molybdenum	lead	zinc
nickel	cadmium	

Note: Some of the **commodities** in the list above are **mineral resources** (rocks and minerals), whereas others are elements extracted from mineral resources.

Use what you have learned about mineral resources as well as information about your specific commodity to draw a concept map showing:

- The geologic nature of the resource: for example, what is the mineral resource and the resultant commodity (mineral, rock, or element); what mineral and rock forming processes acted to create the commodity; in what geologic/geographic settings might these processes have occurred?
- Physical characteristics of the resource.
- The factors and people (people could be countries, companies, etc.) who determine the demand for the resource: for example, what is the commodity used for, who uses it, and what other things might influence the demand for this resource?
- The methods of mining and processing the commodity: for example, how and where does mining and processing occur; what environmental impacts occur; who is impacted by the overall mineral recovery process and in what ways?

Ideally, you should start this as soon as possible, filling in as much as you already know. Throughout this module, **add to your concept map** as you learn more about the commodity you choose and about mineral resources in general. You will use materials that you are learning in class, but you will also need to do *extra research and work outside of the class.*

Resources that may be helpful in addition to class may include your textbook, the USGS Minerals Yearbook website (http://minerals.usgs.gov/minerals/pubs/myb.html), the Mineral Information Institute website (http://www.mii.org/welcome), as well as other webpages. When you turn in the assignment, please include a list of the sources (with web addresses as appropriate) that you used to complete your concept map, although you do not have to denote which information you obtained from each source.

links to interesting videos:
tantalum - https://www.youtube.com/watch?v=euISyPnK0ag
tungsten - https://www.youtube.com/watch?v=E2haKbrLbOQ
tin - https://www.youtube.com/watch?v=u6KxzGMF4co
gold - https://www.youtube.com/watch?v=1RavnNnv5ns
gypsum
halite
copper
bauxite

cobalt
iron
cadmium
chromite
lead
lithium
nickel
platinum (Platinum group metals)
REEs
silica
sulfur
zinc
clay
phosphate
diamonds (industrial, not gemstones)

Rubric for Concept Map

	Exemplary 4	Exceeds standard 3	Meets standard 2	Below standard 1	Score
Organization	• Well organized • Logical format • Map is “treelike” and not stringy • Follows standard map conventions	• Thoughtfully organized • Easy to follow most of the time • Follows the standard map conventions	• Somewhat organized • Somewhat incoherent	• Choppy and confusing	
Geologic nature of the resource					
Content	• All of the main concepts from the module are covered	• Almost all of the main concepts from the module are included	• The majority (>50%) of concepts from the module are included	• Many of the main concepts from the module are missing	
Connections	• The map answers the key questions asked in the instructions • Uses appropriate terminology (terms used in class) • All nodes (concepts) are accurately connected • Links are precisely labeled • Linking words demonstrate conceptual understanding • No misconceptions/errors evident	• The map answers most of the key questions asked in the instructions • Uses appropriate terminology (terms used in class) • All nodes (concepts) are accurately connected • Connections are clear and logical. They connect concepts to promote clarity and convey meaning. • Linking words are easy to follow but at times ideas unclear or connections incorrectly labeled • May contain some small errors	• The map answers some of the key questions asked • Most words are accurately connected • Connections are somewhat clear and convey some meaning • Makes some incorrect connections • Some links are not labeled • May contain errors	• The map answers some of the key questions asked • Only some concepts are accurately connected • Labels aren’t clear, they convey little meaning and do not promote clarity • Many links are not labeled • May contain many errors, and/or concepts that don’t belong	
Factors and people who determine resource demand					
Content	• All of the main concepts from the module are covered	• Almost all of the main concepts from the module are included	• The majority (>50%) of concepts from the module are included	• Many of the main concepts from the module are missing	
Content and connections	• The map answers the key questions asked in the instructions • Uses appropriate terminology (terms used in class) • All nodes (concepts) are accurately connected • Links are precisely labeled • Linking words demonstrate conceptual understanding • No misconceptions/errors evident	• The map answers most of the key questions asked in the instructions • Uses appropriate terminology (terms used in class) • All nodes (concepts) are accurately connected • Connections are clear and logical. They connect concepts to promote clarity and convey meaning. • Linking words are easy to follow but at times ideas unclear or connections incorrectly labeled • May contain some small errors	• The map answers some of the key questions asked • Most words are accurately connected • Connections are somewhat clear and convey some meaning • Makes some incorrect connections • Some links are not labeled • May contain errors	• The map answers some of the key questions asked • Only some concepts are accurately connected • Labels aren’t clear, they convey little meaning and do not promote clarity • Many links are not labeled • May contain many errors, and/or concepts that don’t belong	

Continued on the next page

	Exemplary 4	Exceeds standard 3	Meets standard 2	Below standard 1	Score
Resource mining and processing					
Content	• All of the main concepts from the module are covered	• Almost all of the main concepts from the module are included	• The majority (>50%) of concepts from the module are included	• Many of the main concepts from the module are missing	
Connections	• The map answers the key questions asked in the instructions • Uses appropriate terminology (terms used in class) • All nodes (concepts) are accurately connected • Links are precisely labeled • Linking words demonstrate conceptual understanding • No misconceptions/errors evident	• The map answers most of the key questions asked in the instructions • Uses appropriate terminology (terms used in class) • All nodes (concepts) are accurately connected • Connections are clear and logical. They connect concepts to promote clarity and convey meaning. • Linking words are easy to follow but at times ideas unclear or connections incorrectly labeled • May contain some small errors	• The map answers some of the key questions asked • Most words are accurately connected • Connections are somewhat clear and convey some meaning • Makes some incorrect connections • Some links are not labeled • May contain errors	• The map answers some of the key questions asked • Only some concepts are accurately connected • Labels aren't clear, they convey little meaning and do not promote clarity • Many links are not labeled • May contain many errors, and/or concepts that don't belong	
Includes references (1)					
Legible with (mostly) correct spelling (1)					
Total (out of 30)					

Human's Dependence on Earth's Mineral Resources
Unit I
People, Products, and Minerals
Post-class homework

Learning objectives

- Infer the relationships between sustainability, resource availability, population growth, and economic development.
- Extrapolate the impacts of growing populations and economic development on mineral resource extraction and use.

Population, economic development, and mineral resource use

In 1900, an estimated 1.65 billion people lived on Earth. Today, the population is more than 7 billion and still growing. By 2100, it is believed that an estimated 8–11 billion people will inhabit the Earth.

Every organism needs resources to provide food, water, shelter, and a location for waste disposal/processing. These resources are provided by the environment, which may include other organisms. Humans are unique in that we utilize so much of the planet for resource extraction and waste disposal to meet our needs and our desires. Our ability to innovate and act has enabled many of us in the developed world to enjoy a high standard of living, reshaping resources into "stuff" and consuming beyond our basic needs. For example, in 2005, the United States used 15% of extracted mineral resources but is only home to 5% of the world's population (Gierlinger and Krausmann, 2011).

→ Watch the TED talk "Global Population Growth, Box by Box" given by Hans Rosling (approximately 10 minutes) at: http://www.ted.com/talks/hans_rosling_on_global_population_growth.html. There is an "Interactive Transcript" in the bottom right corner of the video if you want to read along. It might be helpful to read through the questions below before you watch the video.

1) Write down 10 items that you own that you feel you need in our modern U.S. society but that are in excess of truly basic survival needs (such as food, water, shelter, etc).

2) Circle any of the items on the list above (#1) that you think are likely to be owned by someone in an impoverished country.
3) In what ways might population growth affect mineral resource extraction and use? Explain your answer.

4) Rosling, in this TED talk, foresees an end to population growth. What factors does Rosling cite as reasons why population will stop growing? (These factors lead to an increase in child survival rate and a decrease in birth rate.)

5) In what ways might increased economic development (more impoverished countries becoming emerging economies, and more emerging economies becoming developed countries) affect mineral resource extraction and use? Explain your answer.

Citation: Gierlinger, S., and Krausmann, F. 2012. "The Physical Economy of the United States of America." *Journal of Industrial Ecology* 16: 365–77.

People, Products, and Minerals
Unit 1/Activity 3

Economic Development and Resource Use

Learning Outcomes

- Infer the relationships among sustainability, resource availability, population growth, and economic development

Economic Development and Resource Use

The gross domestic product (GDP) of a country is frequently used as an indicator of a country's economic performance and its level of development. A per capita GDP is the overall GDP divided by the number of people in that country and can be used to more easily compare the economic performance of countries with different population sizes.

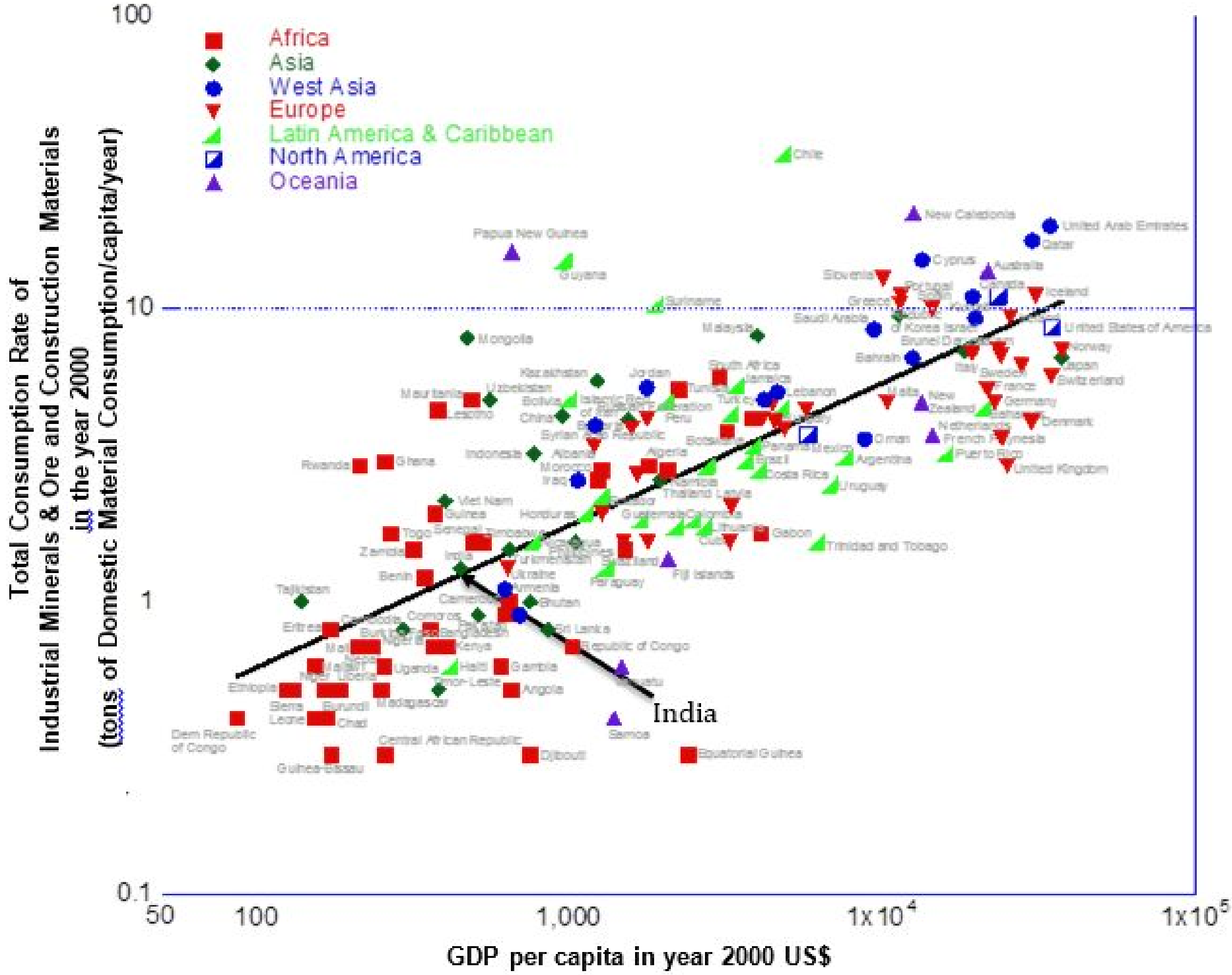


Figure 1. ***The relationship between gross domestic product (GDP) per capita and the total domestic consumption rate of industrial minerals & ore and construction material in tons per capita for ~150 different countries in the year 2000*** (Modified from UNEP Decoupling Report, 2011; Consumption (metabolic) rate data from Steinberger et al., 2010; GDP data from http://data.worldbank.org/indicator/ NY.GDP.PCAP.KD); Country region from http://unstats.un.org/unsd/methods/m49/m49regin.htm with the exception of considering Mexico as part of North America). Not all the countries plotted are labeled above due to space restrictions.

The plot above shows the per capita GDP of many countries versus a measure of their natural resource *consumption rate*. In this case, *consumption rate* is the domestic extraction of a material plus its imports minus its exports of those same materials (in tons per capita per year). In this case, the natural resources measured are Industrial Minerals & Ore and Construction Materials. As the legend denotes, different regions of the world are indicated by markers of different colors and shapes.

Questions

1) Provide the names of two countries that consume approximately the same amount of resources but have widely varying per capita GDP's.

2) Provide the names of two countries that have approximately the same per capita GDP but have widely varying total consumption rates.

3) Despite the pairs noted above, use the trend line in Figure 1 to describe the overall relationship between a country's wealth, as defined by its per capita GDP, and the amount of natural resources used (per capita), as defined by its total consumption rate.

4) Is India more or less developed (as determined by per capita GDP) than most of the Latin American and Caribbean countries (which includes South America)?

5) Using this trend (from #3) predict what will happen as India's economy grows.

Figure 2 (*below*) shows consumption and extraction trends for various types of products in three different regions (North America, South America, and India) since around 1970.

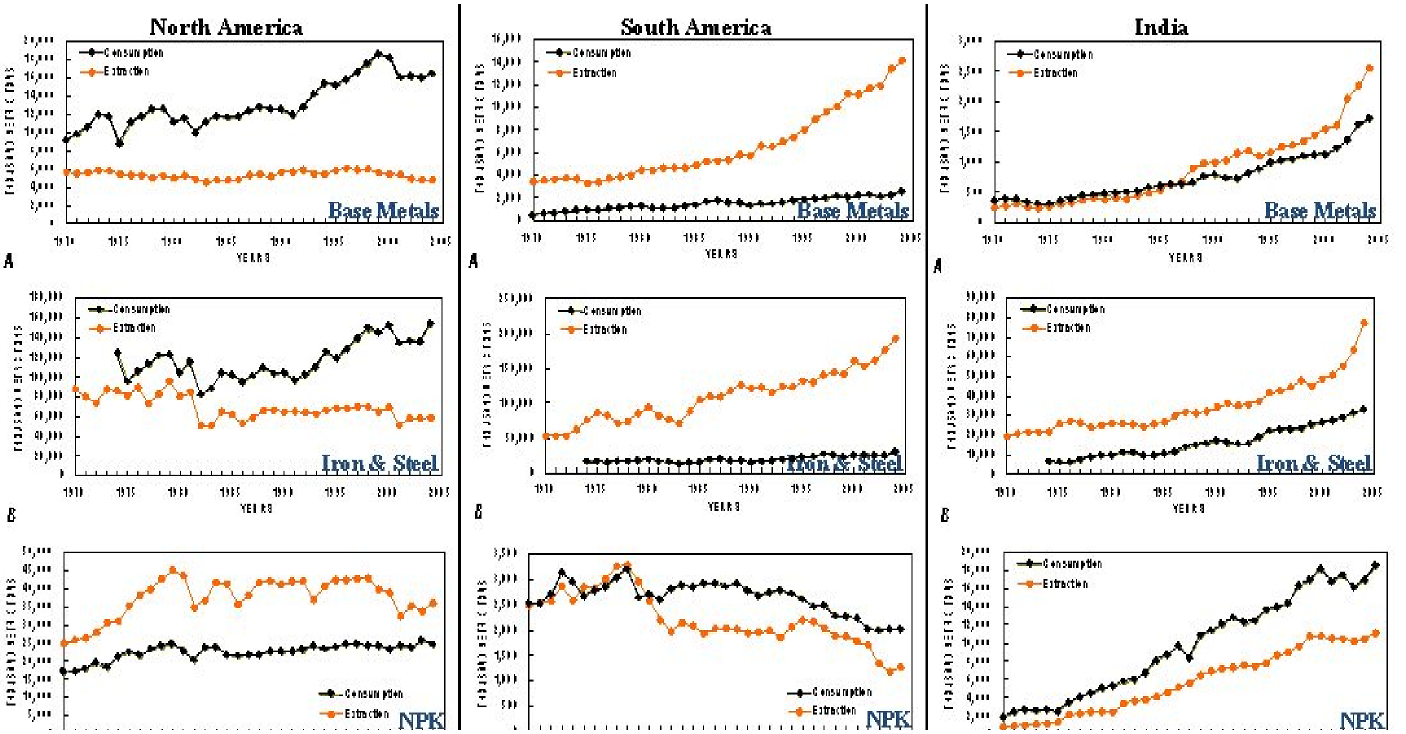


Figure 2: ***Consumption and extraction of various specific commodities in thousand metric tons for North America (left), South America (middle) and India (right).*** **A. Base metals (Aluminum, copper, lead, and zinc); B. Iron and steel; C. NPR (Nitrogen, phosphorus, and potassium), components often used in the production of fertilizer. From Rogich and Matos, 2008. North America includes the Canada, the United States, and Mexico.**

6) Describe the trends in consumption (toward more recent times) for all three regions.

7) Give a possible explanation for the trends in consumption in India. In North America?

8) India currently uses more NKP than South America, even though India is less developed. Why might that be the case?

Source Information for Figures:

Figure 1 Consumption (Metabolic) Rate data:

Steinberger, J., Krausmann, F., and Eisenmenger, N. (2010). "The Global Patterns of Materials Use: A Socioeconomic and Geophysical Analysis." *Ecological Economics* 69, no. 5: 1148–58. Data downloaded for plotting from: http://www.uni-klu.ac.at/socec/inhalt/3812.htm (see "Get data" link).

Figure 1 GDP per capita for constant 2000 US$ data for the year 2000:

Downloaded from http://data.worldbank.org/indicator/NY.GDP.PCAP.KD.

Figure 1 Country Classification:

From the United Nations Statistics Division at http://unstats.un.org/unsd/methods/m49/m49regin.htm. Exception is that Mexico is considered on the plot to be part of North America, rather than Latin America/Central America.

Figure 1 concept (and general source of information):

Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E. U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A., and Sewerin, S. (2011). *Decoupling Natural Resource Use and Environmental Impacts from Economic Growth.* A Report of the Working Group on Decoupling to the International Resource Panel. United Nations Environment Programme. Downloaded from http://www.unep.org/resourcepanel/decoupling/files/pdf/decoupling_report_english.pdf on November 15, 2012 (Figure 2.6 on page 14).

Figure 2: Data and concept

Rogich, D. G., and Matos, G. R. (2008). "The Global Flows of Metals and Minerals." U.S. Geological Survey Open-File Report 2008-1355. 11 pg., available only online at http://pubs.usgs.gov/of/2008/1355/.

Other Information:

Fridolin, K., Gingrich, S., Eisenmenger, N., Erb, K.-H., Haberl, H., and Rishcer-Kowalski, M. (2009). "Growth in Global Materials Use, GDP and Population During the 20th Century." *Ecological Economics,* 68, no. 10: 2696–705.

Gross Domestic Product. *Encyclopedia Britannica* http://www.briannica.com/EBchecked/topic/246647/gross-domestic-product-GDP) (accessed November 15, 2012).

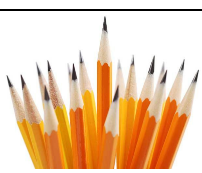
SERI, 2011. Global Resource Extraction by Material Category 1980–2008. . http://www.materialflows.net/trends/analyses-1980-2008/global-resource-extraction-by-material-category-1980-2008/ (accessed September 12, 2012).

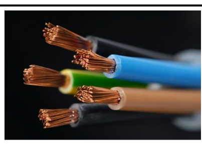
Humans' Dependence on Earth's Mineral Resources
People, Products, and Minerals
Part I: Minerals and Products

Here is a list of the minerals, and their chemical formulas, that we have in class today. Use this, and other properties of the minerals (such as hardness, color, etc.), to match them to the products listed on the back of this sheet (one mineral per product).

Mineral Name	Chemical Formula
Apatite	$Ca_5(PO_4)_3(F,Cl,OH)$
Bauxite	$Al(OH)_3$ - $AlO \cdot OH$
Barite	$BaSO_4$
Calcite	$CaCO_3$
Chalcopyrite	$CuFeS_2$
Galena	PbS
Graphite	C
Gypsum	$CaSO_4 \cdot 2(H_2O)$
Halite	$NaCl$
Hematite (red)	Fe_2O_3
Hematite (specularite)	Fe_2O_3
Kaolinite	$Al_2Si_2O_5(OH)_4$
Muscovite	$KAl_2(AlSi_3)O_{10}(OH,F)_2$
Quartz	SiO_2
Talc	$Mg_3Si_4O_{10}(OH)_2$

Which mineral is in each product? (Choose 1 mineral per product)

Product #	**Products**	**Associated Mineral Name**
  	Toothpaste, Cheerios & Antacid	
 	Glass & Sandpaper	
 	Table Salt & Road Salt	
	Jewelry	
 	Baby Powder & Makeup	
	Pencils	

	Drywall & Plaster	
	Sparkly Eye Shadow	
	Blush	
	Car Battery	
 	Porcelain	
	Copper Wire, Pennies & Matches	
	Aluminum Foil	
	Fertilizer	
	Mud Flap of Truck	

The Economics of Minerals:
Rechargeable Batteries and Mineral Resource Use

Learning objectives

By completing this activity and the homework, you will:

- Identify the mineral resources used in rechargeable batteries.
- Describe overall trends graphed for production and value (price) of nickel, cadmium, lithium, and lead, and identify changes in trends and/or anomalous features in the graphs.
- Explain trends, changes over time, and anomalies in terms of mine production, demand, recycling, changes in battery technology, regulation due primarily to health concerns, and/or population growth.
- Use a concept map to interpret the complex relationships among consumers, producers, regulating agencies, and the environment in a global context.
- Examine your own consumer behavior and judge the impacts of this behavior on sustainability.

Introduction

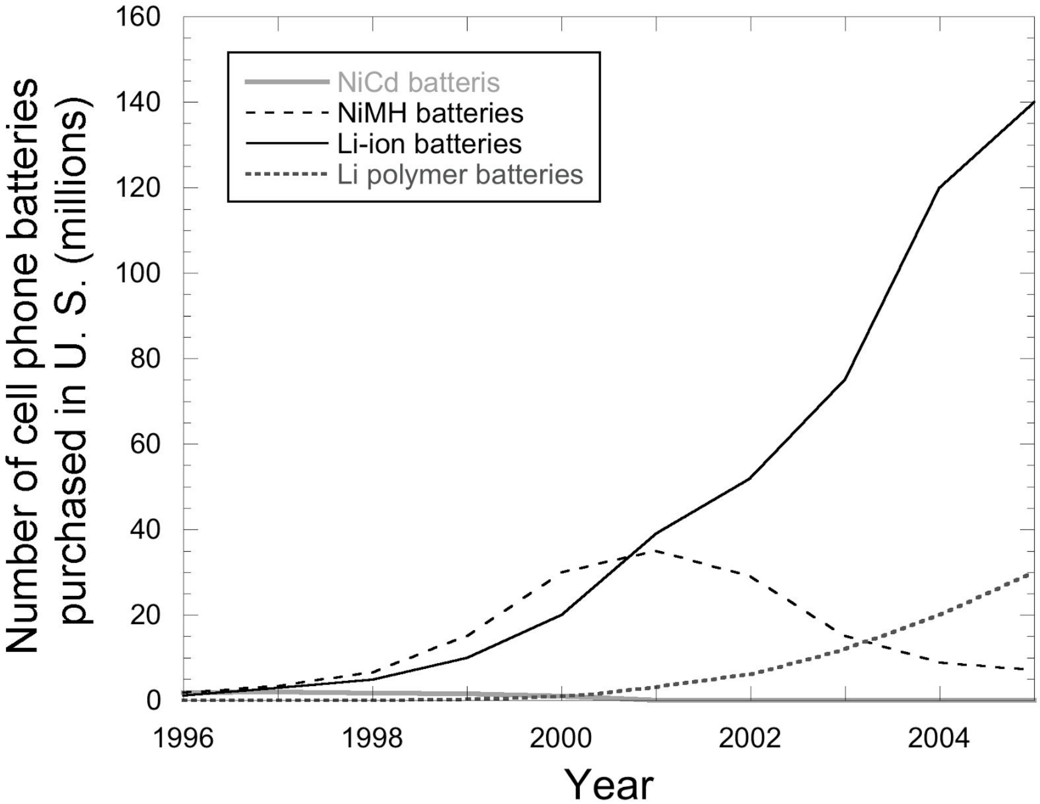
Mineral resources are important because they are used to make products. Thus consumers drive the quest for mineral resources, and economics play a large role in whether and how much minerals are mined.

In this activity, you will consider the mineral resources used to make rechargeable batteries, and the economic factors and consumer choices that influence the supplies of these mineral resources.

You need to know that there are five main types of rechargeable batteries: acid-lead, NiCd (nickel cadmium), NiMH (nickel metal hydride), Li-ion (lithium ion), and Li-polymer (lithium polymer).

Part 1A. Changing technology: cell phone batteries

In this part, we'll look specifically at batteries themselves. Use the graph below, which shows the number of cell phone batteries purchased annually in the United States, to answer questions 1–3.



1. Summarize in what ways the number of cell phone batteries has changed since 1996. You can write different answers for the different types of batteries.

2. Why do you think that the number of batteries used has changed?

3. The graph shows consumption of cell phone batteries in the United States. What do you think a graph showing global consumption would look like? Why?

Part 1B. Changing technology: car batteries

One important characteristic of batteries is their energy density. This tells how much energy (in Watt-hour) is contained is in a given mass (kilogram). We want a battery that has a lot of energy for its size. Cost is another consideration. Safety is also a factor; we want batteries that do not cause laptops (or cars) to explode! The table shows energy densities and approximate costs of the different types of rechargeable batteries. Use the table to answer questions 4–8.

Rechargeable battery type	Energy density (Wh/kg)	Approximate battery cost
Lead-acid	30–50	$25 (6 V)
NiCd	45–80	$50 (7.2 V)
NiMH	60–120	$60 (7.2 V)
Li-ion	110–160	$100 (7.2 V)
Li-ion polymer	100–130	$100 (7.2 V)

Standard car batteries are lead-acid batteries. Batteries in hybrid-electric and plug-in-electric cars are either NiMH (for example, in the Toyota Prius) or Li-ion (for example, in the Chevy Volt).

4. Why are the newer electric cars using Li-ion batteries?

5. Why are lead-acid batteries still used in gasoline-engine cars?

6. In what ways do you think demand for lead, lithium, and nickel will change in the future? Explain your reasons.

7. Each car battery contains about 21 lbs. of lead. Car ownership is expanding in developing countries. In 2011, there were 75 million motor vehicles owned in China (there were about 240 million owned in the United States). China is expected to own 200 million motor vehicles by 2020. Assuming these vehicles will be standard gasoline-burning cars, each with an acid-lead battery, how much more lead (in tons) would need to be produced to meet the demand? To answer this, you need to know that there are 2204.6 lbs. in one metric ton.

8. List several consequences that might arise from the increased demand.

Part 2A. Using the concept map to make predictions

The elements nickel and lithium are used in the batteries we just considered. Let's consider what factors might impact the amount of nickel and lithium mining.

The following events affected the price/value of either nickel or lithium, because they affected either the supply or demand of these commodities.

9. Based on the concept map, how (and why) should each of the following events affect either nickel (Ni) and/or lithium (Li) demand or supply and price?

   Example: The only two lithium mines in North Carolina closed: 1986 and 1998
   This should reduce Li production, which would lower supply and thus increase Li price.

   - First commercial Li-ion battery: 1991

   - EPA classifies cadmium as Group B1 probable human carcinogen (cadmium is used with nickel in NiCd batteries): 1992

   - Three new nickel mines/plants open in Australia: 1998–2004

   - First commercial HEV (hybrid-electric car) introduced to U.S. market: 1999 (until 2008, all used NiMH batteries)

- Global recession December 2007–2009

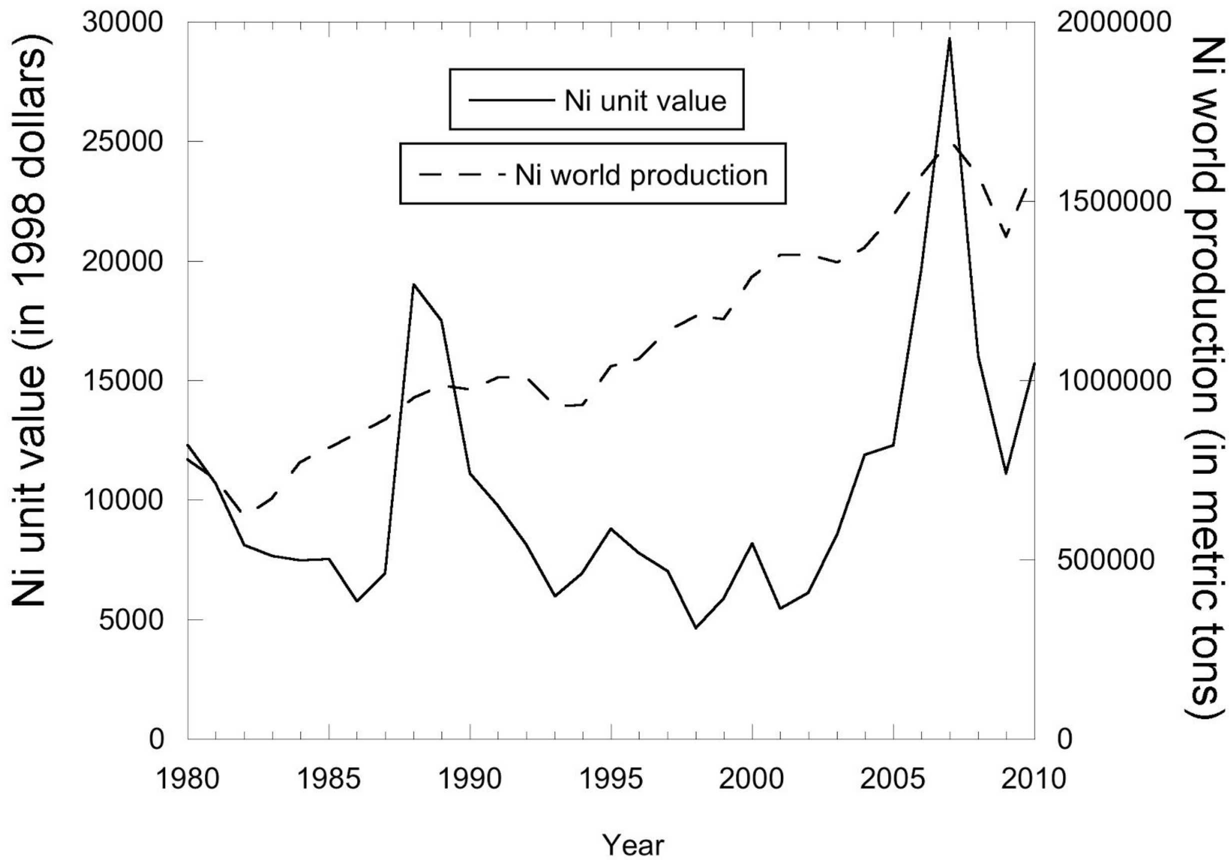
These other events also may have impacted either lithium or nickel demand, supply, and price:

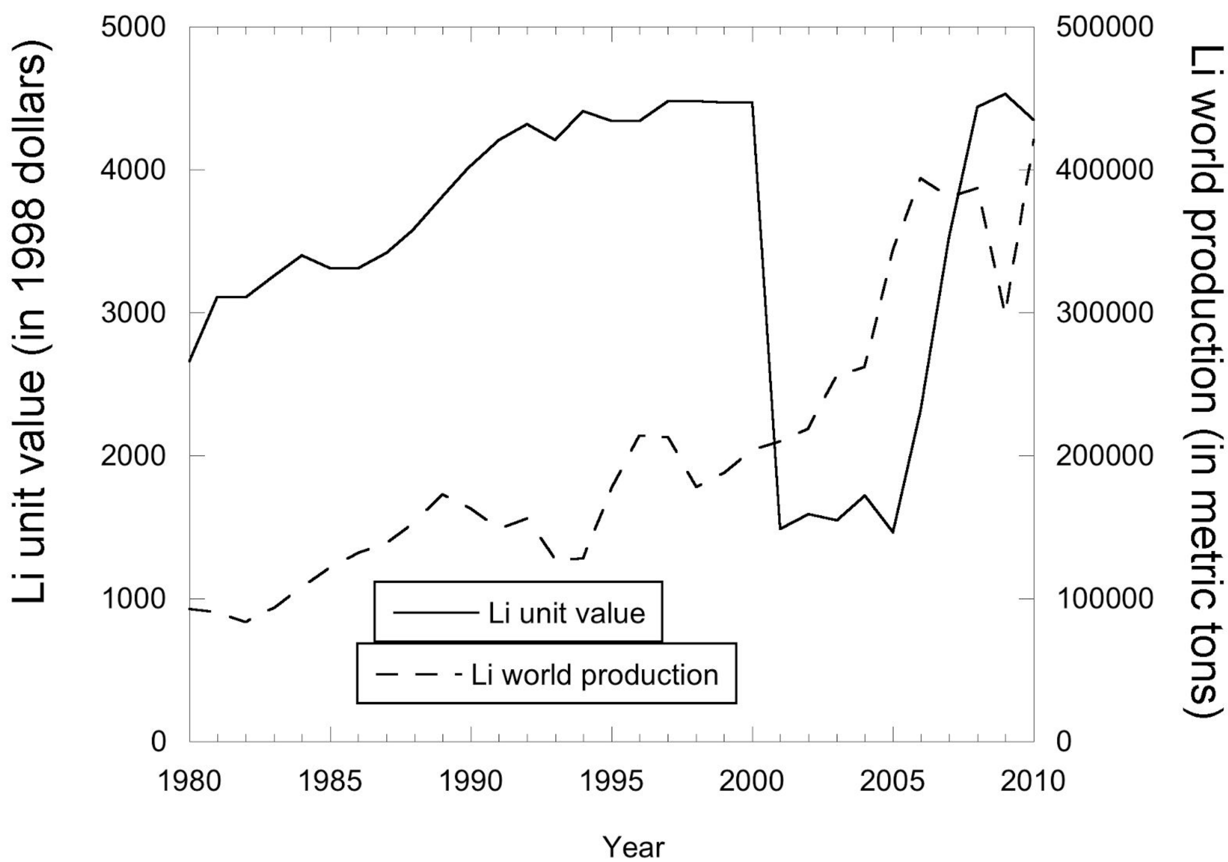
- First NiMH batteries appeared in consumer goods: 1989
- Congress passes Mercury Containing and Rechargeable Battery Act (facilitates recycling of NiCd batteries): 1996
- Large exports of scrap metal (containing nickel) from Russia: 1996–1998
- Improvements in PAL processing technology (used for nickel): 2000
- American Recovery and Reinvestment Act—money spent on rechargeable battery technology (including opening a Nissan LEAF [electric car] plant in 2010): 2009
- First plug-in electric vehicles (LEAF, Volt: these use Li-ion batteries): 2010

Part 2B. Testing your predictions against data

Use the graphs of nickel (Ni) and lithium (Li) production (production = mining and recycling) and value (price) to answer this question. The values are given in price (in 1998 dollars, to remove effects of inflation) per metric ton.

10. Pick two predictions you made in #9. Explain how data presented in the graphs of Ni and Li production and price support or refute your predictions.





Graphs to use for part 2B.

Data sources

Graphs in this activity were created by J. Branlund, using data from the following sources:

- Data Presented in the Graphs of Value/Price and Production are from Historical Statistics for Mineral and Mineral Commodities in the United States. USGS Data Series 140. Available at http://minerals.usgs.gov/ds/2005/140/.

- Data on Number of Batteries and Metals in Batteries are from D. R. Wilburn (2008), "Material Use in the United States—Selected Case Studies for Cadmium, Cobalt, Lithium, and Nickel in Rechargeable Batteries," USGS Scientific Investigations Report 2008-5141. Available at http://pubs.usgs.gov/sir/2008/5141/.

- Battery Energy Density and Cost is from Isidor Buchmann, *Batteries in a Portable World.* Available at http://www.buchmann.ca/.

Rare Earth Elements: Supply, demand, consumption, price

Rare Earth Elements (REE) are extensively used every day in batteries, electronics, ceramics, and high-powered magnets, and they are vital for clean energy technologies as well. In this activity we will look at REE supply, and consumption and price data, and discuss possible future strategies for balancing REE supply and demand.

China supplies the majority of the world's REE. The Chinese government sets the maximum amount of REE that can be legally exported out of the country (i.e., **export quota**) each year. The following table shows the amount of the export quota each year for the years 2000–2010 (except for 2002, for which we have no data), and the price per ton of REE adjusted for inflation with respect to the value of U.S. dollars (USD) during 1998 (shown as 98$/t, which means 1998 dollars per ton).

Year	**Total export quota (metric tons)***	**REE price per ton** in USD during 1998, expressed as (98$/t)**
2000	47,000	6,110
2001	45,000	5,330
2002	N/A	6,800
2003	40,000	5,450
2004	45,000	7,410
2005	65,580	5,500
2006	61,070	3,150
2007	59,643	4,160
2008	49,990	10,300
2009	48,155	7,100
2010	30,258	14,500

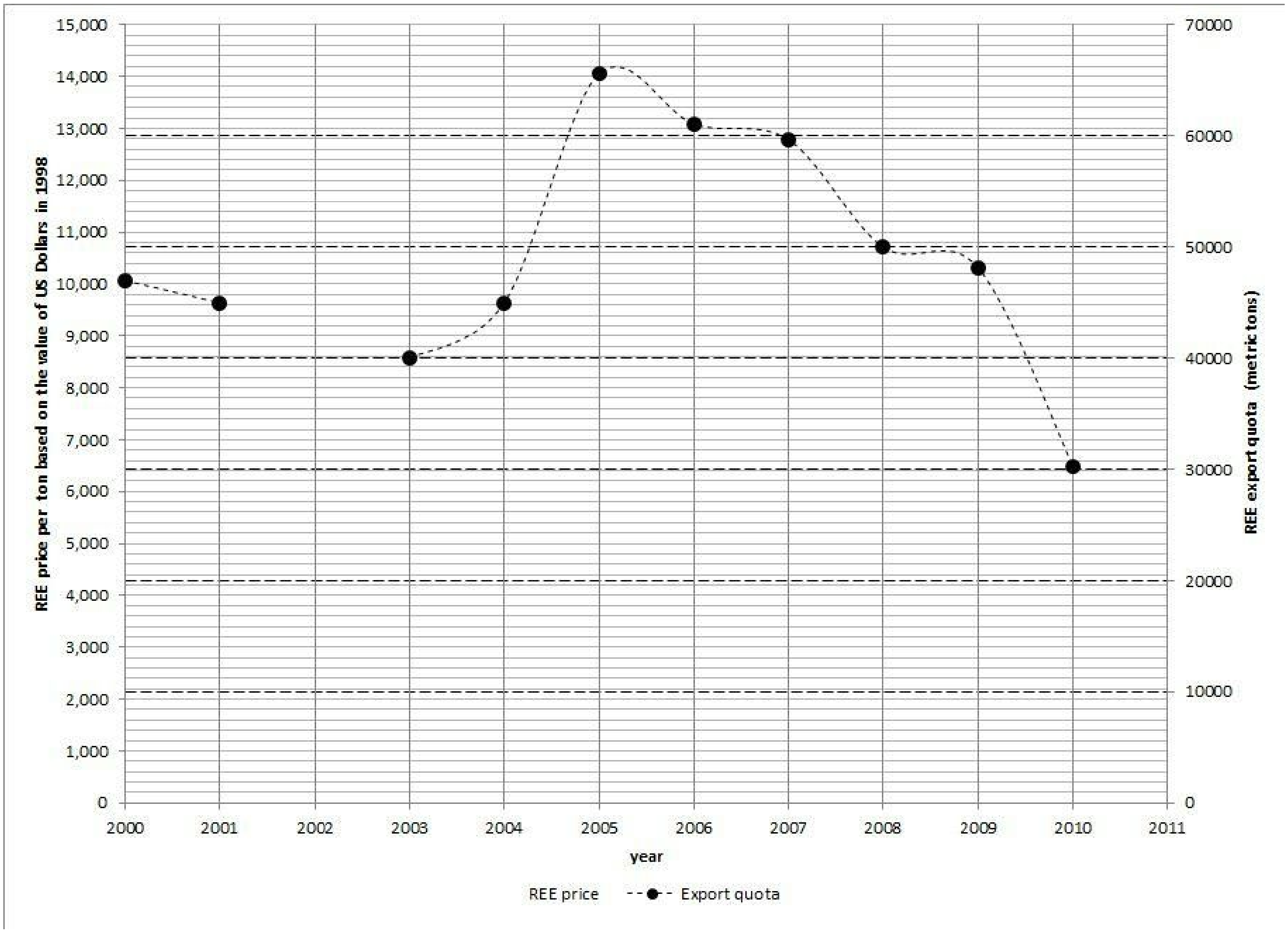
* Quota data from "China's Rare-Earth Production, Consumption, and Export Quotas for 2000 through 2011." (Tse, Pui-Kwan, 2011, China's Rare-Earth Industry: U.S. Geological Survey Open-File Report 2011–1042, 11 p.) Data from 2005 onward show total export quota for domestic producers and traders, plus Sino–foreign joint ventures.

** Price data from: "U.S. Geological Survey, 2011, REE statistics," in Kelly, T. D., and Matos, G. R., comps., "Historical Statistics for Mineral and Material Commodities in the United States," U.S. Geological Survey Data Series 140, at http://pubs.usgs.gov/ds/2005/140/.

1. The amount of REE allowed to be exported out of China is plotted on the graph below. Plot the REE price from the above table (the third column) on the same graph, using connected symbols.

Please use a different symbol (not a filled circle) for your plot, and indicate your symbol on the legend below the graph.

Note: This graph has TWO vertical axes. The <u>vertical axis on the left</u> indicates the price of REE expressed in terms of dollars per ton adjusted for inflation (98$/t). <u>Use this axis for the data you need to plot</u>. The vertical axis on the right shows the amount of REE export quota from China for the years listed. This data is already plotted for you.

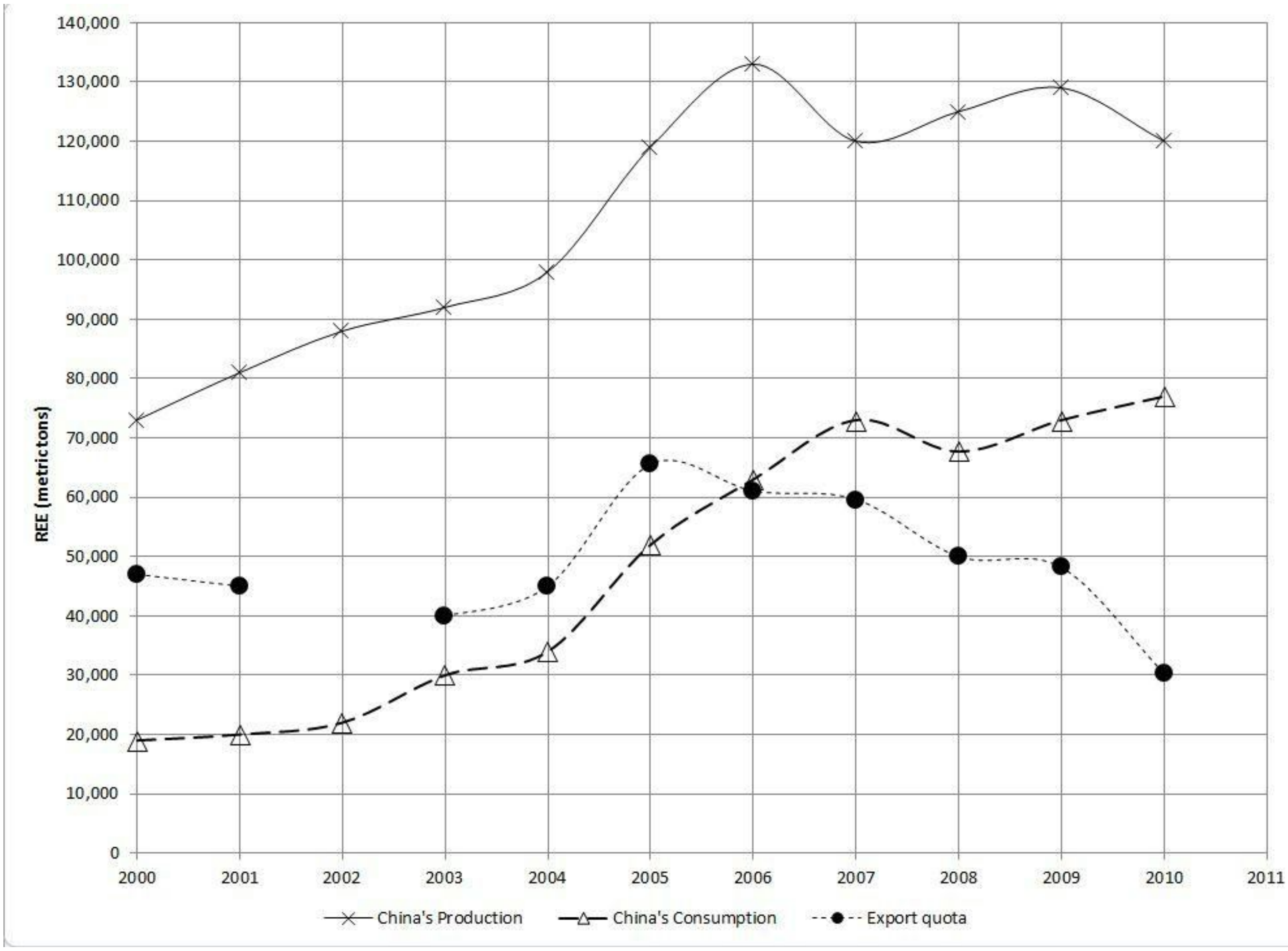


Answer the following questions based on the plot shown above:

2. The trend of the REE export quota is shown by black dots and the dotted line. By how much was the REE export quota reduced between 2005 and 2010?

3. When did the price of REE reach its lowest value? What was the approximate lowest value for REE?

4. Based on this graph, what can you say about the relationship between the REE export quota out of China (supply) and the price of REE?



5. China's REE production (Xs), consumption (open triangles), and export quota (filled circles) for 2000–2011 are shown in the above chart. Why do you think China is currently reducing its export quota? Give two reasons.

Rare Earth Element	Partial list of uses in clean energy technology fields				Demand* (Tons)	Supply* (Tons)
	Magnets (to generate electricity, in wind turbines, hybrid cars, etc.)	NiMH batteries in some hybrid cars	Phosphors in energy-efficient light bulbs (CFL)	Catalysts in cars (catalytic converters, to reduce pollutants)		
Lanthanum		**X**	**X**	**X**	41,200	30,500
Cerium		**X**	**X**	**X**	43,900	38,400
Praseodymium	**X**	**X**		**X**	9,800	7,000
Neodymium	**X**	**X**			27,000	24,400
Europium			**X**		400	390

*Data from Roger Bade (2010), "Rare Earth Review: Is the Hype Justified?"
http://www.slideshare.net/RareEarthsRareMetals/libertas-rareearthreview

6. Some common uses, demand, and supply, for five of the rare earth elements are shown in the above table. You'll notice that supply and demand are out of balance. What can consumers, REE producers (e.g., mining companies), and technology manufacturers do to reduce the imbalance, and how will these actions affect the adoption and use of clean-energy technologies? Create a concept map to illustrate your answers.

Optional end-of-unit reflection question (this can also be used as a post-unit homework assignment or can be used as a unit-based question for an exam)

7. Describe two measures that you can personally take to reduce the supply/demand imbalance of REEs. Explain how those measures could either increase REE supply or reduce REE demand or both.

Humans' Dependence on Earth's Mineral Resources
Unit 3
Mining and Mining Impacts

Part II: Ore Grades, Waste, and Remediation

Learning objectives

- Use spatial and quantitative skills to interpret geological information.
- Calculate the amount of metals obtained and the amounts of waste created through mining.
- Evaluate the impacts of various factors on an ore's cut-off grade.
- Compare the pros and cons of continuing mining in an area and weigh different remediation approaches.

Assignment Directions

The class will divide into small groups. Each group will work on a different section of this assignment. There are three different sections.

Once your group completes a section of the assignment, please see me for the next section.

You will have a total of 20 minutes to complete this activity.

Humans' Dependence on Earth's Mineral Resources
Unit 3
Mining and Mining Impacts

Part II: Ore Grades, Waste, and Remediation

Section I: Mining and Waste

Golden Sunlight Mine (GSM), near Whitehall, Montana, opened in 1983 and is still open today. It is one of the properties owned by the Canadian company Barrick Gold Corp. Take a look at the attached satellite image of Golden Sunlight Mine. Some remediation (slope stabilization) has been done by planting and growing vegetation on the west side of the West Waste Rock Dump Complex and on the northeast side of the East Waste Rock Dump Complex.

1) On the attached satellite image, use a marker to denote the boundaries of mining areas (e.g., draw a line around the Mineral Hill Open Pit Mine area, etc.) and a different color marker to denote the boundaries of waste areas (e.g., draw a line around the West Waste Rock Dump Complex, etc.).

2) Use the boundaries you created to estimate the approximate percentage of land surface area that is used for actual pit mining as opposed to the storage of mining waste products (including both waste rock and tailings). The approximate percentage of land surface used for pit mining as compared to that used in mine waste storage is:
    a. 90–100%
    b. 70–85%
    c. 45–55%
    d. 15–30%

3) For a sense of scale:
    a. Estimate the number of acres inside Tailings Impoundment #2 using the scale box (100 acres) on the map.

    b. If an American football field, including the end zones, is about 1.32 acres, approximately (mathematically) how many football fields would fit inside Tailing Impoundment #2? Show your calculations here.

4) Why might Tailings Impoundment #1 look different than Tailings Impoundment #2?

5) The Montana Department of Environmental Quality (DEQ) has recently received an application from GSM to amend their operating permit. This would include adding one new pit northeast of the mine and extending the larger Mineral Hill pit, although within the previous permit boundary. This additional mine area would extend the life of the mine for two years to 2017, allowing the company to continue to explore

the area without closing. The additional mining would result in an estimated 4.2 million tons of ore and 52.6 million tons of non-ore rock (waste).

a. What is the percentage of ore to waste (by weight) for these new sections? Show your calculations here.

b. What might be some incentives of the DEQ and the community to approve the permit? What might be some incentives not to approve the permit?

Golden Sunlight Mine Satellite Image

Humans' Dependence on Earth's Mineral Resources

Unit 3
Mining and Mining Impacts

Part II: Ore Grades, Waste, and Remediation

Section II: Ore Grades and Mining

The **grade** of an ore is the concentration of the desired material within the rock. There is more metal (a higher concentration) in higher grade metal ores. Ore grades are often given in percentages or in units of ppm (defined below).

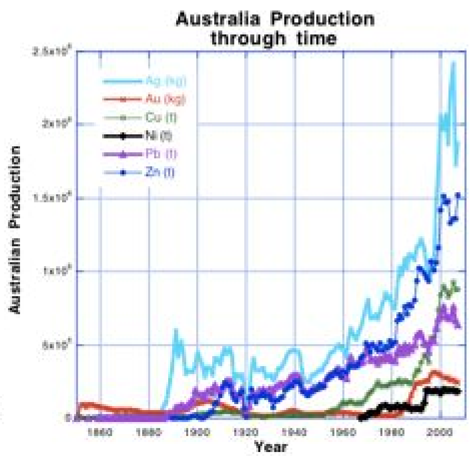
Percentages, which most of us are familiar with through our class grades, are actually a measurement of "parts per total parts." In the case of grades on an exam, if you received a 92% on your 100-point exam, you received 92 points out of a possible 100 points. This is similar to ores: If a nickel ore has a grade of 2%, it means there are 2 pounds of nickel for every 100 pounds of ore. It also means that there are 2 grams of nickel for every 100 grams of ore, etc., so long as the unit of comparison remains the same within the percentage calculation (pounds to pounds or grams to grams or ounces to ounces, etc.).

1) Some sources say that the average single family home in the United States uses about 420 pounds of copper within the plumbing, appliances, building wire, and more. In the twenty-first century, an average copper grade ore might be ~0.6%.
    a. How many pounds of 0.6% grade copper ore needs to be mined in order to obtain 420 pounds of copper? Show your work here.

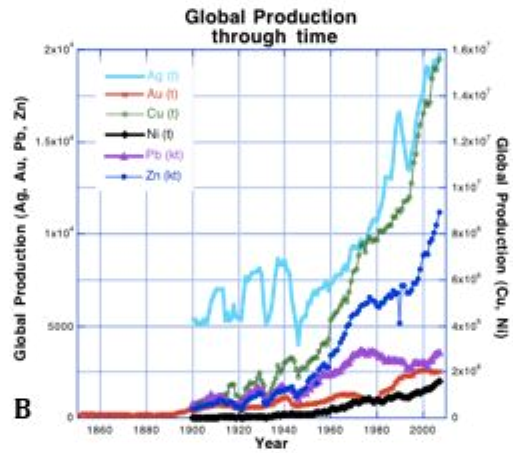
Another frequently used unit of measurement for ore grades is "parts per million" or ppm. Instead of finding the concentration per 100 parts, like the percentage, ppm finds concentration out of one million parts. This unit is used to represent metals that often occur in smaller concentrations. A gold ore with a 2 ppm ore grade would have 2 pounds of gold for every 1,000,000 pounds of ore. An equivalent unit is grams/ton (since there are 1,000,000 grams, or 10^6 grams, in a metric ton). Thus a 2 ppm grade gold ore would also have 2 grams of gold for every ton of ore.

1) A gold coin called a Krugerrand has approximately 31.1035 grams of gold in it.
    a. How many metric tons of 15 ppm grade gold ore need to be mined in order to get enough gold for a *single* Krugerrand? Show your work here. Remember that 1 metric ton = $1x10^6$grams.

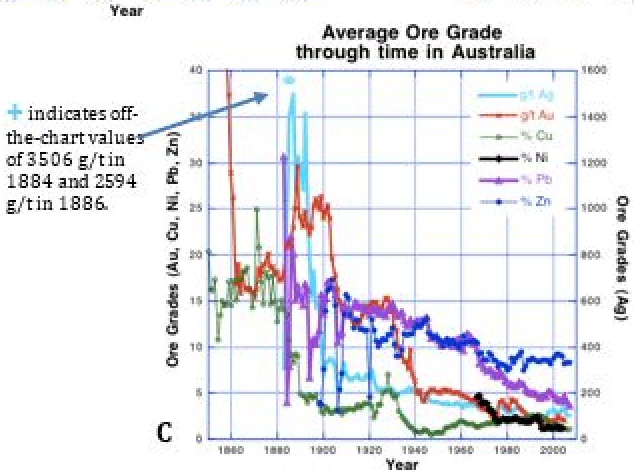
    b. How much waste product (in metric tons) is created? Show your work here.



A



B



The plots A and B above indicate the production of certain metals (Ag, Au, Cu, Ni, Pb, and Zn) in Australia (A) and globally (B) over the period from ca. 1850 to 2007 (where data is available). Plot C shows the average ore grade mined in Australia for these same metals over the same period.

2) Draw an arrow on each of the three plots above to indicate the general trend of the amount of production (A & B) and the grade of the ore (C).

3) If ore grades (the concentration of the metal within the ore) have decreased toward more recent times, yet production of the metal has increased, then what are the implications for:
   a. The amount of ore that must be mined to allow production of the metal to stay the same or to increase?

   b. The amount of waste rock and tailings produced from the processing of that ore?

4) List/explain at least three possible reasons why the ores grades have trended toward lower grade ores in more recent times.

Humans' Dependence on Earth's Mineral Resources
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Mining and Mining Impacts

Part II: Ore Grades, Waste, and Remediation

Section III: Cut-off Grade, Mine Productivity, and Legacy Mines

Many aspects influence the financial productivity of any mine. Obviously the presence of the desired material is key, but both geological and nongeological elements influence the overall success of the mine. Some important factors, in addition to the strategy of the company and their management, include:

Resource Quality: Ease with which the ore can be mined, the type of mineral resource, the size of the ore deposit, ore grade (concentration of desired material within the rock)

Input Costs: Labor, energy, and water use; infrastructure and services; other materials used in the mining process

Macroeconomic Factors: Metal prices, ability to obtain credit and interest rates, exchange rates

Other Factors: Governmental permitting rules, financial resources, social and political factors

Together these factors determine whether a site is worth mining and/or whether a mine will stay open and, if so, for how long. They will also influence the extensiveness of the mine (how much land is mined), the amount of waste products created, the number of jobs maintained, and more. A mining company has some control over only some of these factors.

The **grade** of an ore is the concentration of the desired material within the rock. There is more metal (a higher concentration) in higher grade metal ores. Ore grades are often given in percentages or in units of ppm.

The **cut-off grade** of an ore is essentially the lowest grade of an ore that is worth mining. If the ore grade is less than the cut-off grade, then a mining company will not make money mining that ore. According to Fellows (2010), the cut-off grade of an ore is one of the main factors in determining the economics of the mine.

It might seem as if the cut-off grade of an ore is determined permanently at the time of exploration and mine opening, but actually the cut-off grade changes throughout the lifetime of the mine (and thus, changes the estimates of the amount of ore in a reserve). For example, if cut-off grade drops, the mine is now able to profitably extract metal from an ore with a lower ore grade (a lower concentration of metal in the ore).

1) For the factors listed below, note whether the cut-off grade would likely rise or fall ***and explain why***. The first one (a) is an example:

   a. Increased market price of the metal? Rise or **Fall**
   Explain:
   If the mine can receive more money for each ounce that they produce, then the extra costs of processing more lower concentration ore are worthwhile. Therefore an increased market price could lead to a lower cut-off ore grade.

   b. New beneficiation technologies? Rise or Fall
   Explain:

   c. Better (more equitable) labor agreements? Rise or Fall
   Explain:

d. Rising energy costs? Rise or Fall
Explain:

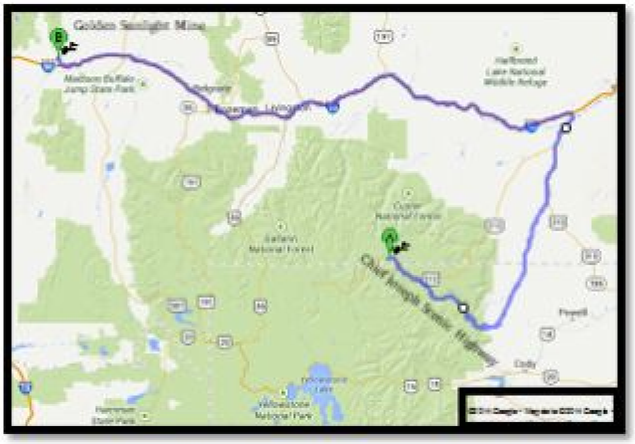
e. More stringent environmental regulations? Rise or Fall
Explain:

2) Many closed mines exist throughout the United States (and other countries). If the cut-off grade drops for ores once extracted from these legacy mines, what might happen to these old mines?

The Golden Sunlight Mine (GSM) near Whitehall, Montana, is relatively close to dozens of legacy mining operations. In the fall of 2012, GSM won an award from the U.S. Bureau of Land Management for helping to reuse materials from legacy silver and gold mines. The GSM partnered with other groups to remove and process the tailings from the legacy mines, deposit the reprocessed tailings into a more modern, lined, tailings pond, and reclaim the old site (all with proper permitting). The partners and related contractors benefit financially, the historic sites are cleaned up with a reduced amount of federal/state (taxpayer) expense, and new jobs are provided. In 2011–2012, GSM had at least 10 different contracts to bring in historic mine materials for processing, including from sites on public lands.

3) These same legacy tailings have been around for a long time and remained untouched for years. What factors might have changed to allow this type of "ore processing" partnership to exist today?

In 2010, the Montana Department of Environmental Quality (DEQ) proposed a plan for the cleanup of the McLaren Tailings Abandoned Mine Site just outside of Yellowstone National Park near Cooke City ("A" on map below). This area was noted to be contributing acid mine drainage to the Soda Butte Creek, which runs through a portion of Yellowstone National Park, and there were concerns about a possible failure of the tailings dam. As proposed in 2010, the plan was to remove approximately one-half million tons of mine waste from the site, most to be placed in a repository near the site, but of which about 20% (~68,700 tons) would be transported for gold processing at GSM. It was believed that for the DEQ/State of Montana, this would break even monetarily; the cost of hauling on this 640-mile round-trip route through both Montana and Wyoming (see highlighted highway section on map) to the Golden Sunlight Mine ("B" on map) would approximately equal the money made by selling the gold tailings, estimated to be $25–30 million.



The plan would require approximately 120 loads to be transported each week (Monday through Friday), averaging 24 round trips each day using double belly haul trucks with a capacity of about 40 tons for one summer (~14 weeks). As commercial hauling vehicles are not allowed in Yellowstone National Park, the trucks must take the longer route noted in the map above.

The tailings contain some substances that can be dangerous to humans or other organisms. Laboratory testing of the tailings (stabilized for easier hauling) indicated that values of cadmium, copper, iron, mercury, and silver were significantly above background levels; in particular, concentrations of iron and copper were above the target concentrations for residential exposure. However, the tailings were below the limits established by the Toxicity Characteristic Leaching Procedure and therefore not classified by the Environmental Protection Agency (EPA) as Hazardous Material.

In the end, this plan to transport the tailings to GSM was nixed based particularly on voiced concerns from Wyoming about the intense use of the Chief Joseph Scenic Highway (see on map above), which has very curvy sections and is one of the steepest roads in the area (up to 7% slope), to transport the tailings. Instead, the new plan calls for all the tailings material to be placed in the nearby repository, which was deepened in design in order to accommodate the total amount from the McLaren site.

4) Please explain some potential positive aspects of the proposal to haul the legacy tailings to GSM to extract the gold. In what ways would this have been a good plan?

5) Please explain some potential negative aspects of the proposal to haul the legacy tailings to GSM to extract the gold. In what ways might this not have been a good plan?

6) If you were a resident of Wyoming near this area, what concerns might you have had about this proposal to haul to GSM?

Humans' Dependence on Earth's Mineral Resources
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Sources/References

Plots and Figures

Section I:

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"Barrick Golden Sunlight: Current and Future Operations—Mine Design, Operations, and Closure Conference." 2012. Downloaded from http://www.mtech.edu/mwtp/conference/2012_presentations/Seth%20Slatter.pdf. (See for information on future south possible extension of Mineral Hill and new northeast pit mine)

*Final Supplemental Environmental Impact Statement Golden Sunlight Mine Pit Reclamation, c*hapters 1 and 3. 2007. Montana Department of Environmental Quality and U.S. Department of Land Management. Downloaded fromhttp://deq.mt.gov/eis/hardrock/GoldenSunlightSEIS/finalSEIS.mcpx.

Google Earth for base map.

Section II:

Data for plots from: Mudd, G. M. 2009. "The Sustainability of Mining in Australia: Key Production Trends and Their Environmental Implications for the Future." Research Report No RR5, Department of Civil Engineering, Monash University and Mineral Policy Institute, Revised April 2009. Downloaded fromhttp://users.monash.edu.au/~gmudd/files/SustMining-Aust-Report-2009-Master.pdf.

Section III:

Map ©2014 Google – Map data

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"Fact Sheet—McLaren Tailings Reclamation Project December 2010: McLaren Tailings Reclamation Project Transportation Proposal Withdrawn, Waste Disposal Facility Redesigned." Montana Department of Environmental Quality, 2 pages. Downloaded fromhttp://deq.mt.gov/AbandonedMines/pdfs/ProjectDocuments/McLaren/FINAL%20Fact%20Sheet%20McLaren_12-10.

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The Science of Fracking – Gregory Lackey, Katya Hafich, Daniel Birdsell (University of Colorado Boulder), Lisa Gardiner (UCAR Center for Science Education) and Tori Hellmann (Palisade High School).

AGU GIFT: The Science of Fracking

Presenter Bios

Daniel Birdsell (Daniel.Birdsell@colorado.edu) is pursuing a PhD at the University of Colorado in Civil Engineering. He studies environmental impacts of oil and gas development in the subsurface such as the migration of hydraulic fracturing fluids and the geo-mechanical impacts of Class II disposal wells. He helped teachers in Colorado develop a curriculum for teaching about ecosystem services focused on oil and gas development. Daniel holds a B.S. in Chemical Engineering from the University of New Mexico.

Lisa Gardiner (lisagard@ucar.edu) leads K-12 curriculum development and teacher professional development at the UCAR Center for Science Education. She holds a PhD in Geology from the University of Georgia and an MFA in Nonfiction Writing from Goucher College. She has worked in diverse education settings from universities to nature centers and farms. In her current role, she creates educational experiences for classrooms, blogs, websites, museum exhibits, interactives, and books and instructs teacher PD workshops and online courses.

Katya Hafich (Katya.Hafich@colorado.edu) splits her time at University of Colorado Boulder between coordinating the education and outreach program at the AirWaterGas Sustainability Research Network, and coordinating K-12 and community outreach programs at the CU Boulder Office for Outreach and Engagement. She's a recovering biogeochemist, and now works with K-12 teachers, community groups, and faculty on global issues of climate change and hydraulic fracturing.

Tori Hellmann (tori.hellmann@d51schools.org) is a science teacher at Palisade High School in Palisade, Colorado where she has taught Geophysical Science, Biology, Honors Biology, Zoology, Botany, AP Environmental Science and IB Biology. She is also the advisor for the MESA club, which involves STEM activities and competitions in Colorado. Previously Tori taught middle school science at Holy Family Catholic School in Grand Junction, Colorado. She holds a master's degree in science education from Montana State University and a bachelor's degree in elementary education K-8 from Northern Arizona University. Her interest in science began at Colorado State University where she majored in watershed science. This past summer Tori was a Teacher-in-Residence with the AirWaterGas project, developing science curriculum about the impacts of oil and gas development.

Greg Lackey (gregory.lackey@colorado.edu) is a PhD candidate at The University of Colorado, Boulder. His primary research interest is the multiphase transport of stray methane away from leaky oil and gas wellbores. Greg is also very interested in environmental education. He spent two years working as a teaching resident assistant for the Sustainability and Social Entrepreneurship Residential Academic programs at the University of Colorado. He has also been a part of the education and outreach team for the AirWaterGas Sustainability Research Network.

The Rock Porosity Experiment

Introduction

Students will investigate the porosity and permeability of rock formations that may hold oil, gas, and water.

Credits

Lesson developed by Tori Hellmann, UCAR AirWaterGas Teacher-in-Residence with support from science advisor Jessica Rogers. Adapted from The Absorbancy of Rock from the SEED Science Laboratory Activity Library.

Grade level

6-10

Time Required

Teacher Prep Time: Approximately 15-20 minutes
Class time: One ~90 minute block period

Learning Goal

Students will be able to relate the physical properties of permeability and porosity of rock formations to the amount of water, oil, and natural gas held in these formations.

Standards

Next Generation Science Standards
HS-ESS3-1 Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. ESS3.A

Materials

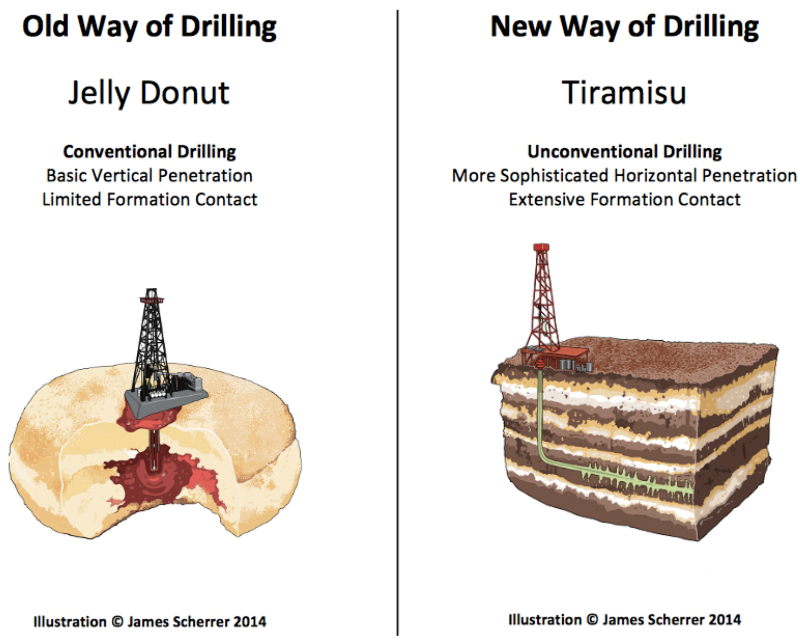
For each lab group:

- A marble, small pieces of chalk (magnesium carbonate)*, pumice, granite, sandstone and shale
- 250mL beaker for each rock sample (6 total)
- Graduated cylinder
- Electronic balance
- Water

*Note: be sure to use **gymnast chalk**, magnesium carbonate, not chalkboard chalk for this activity.

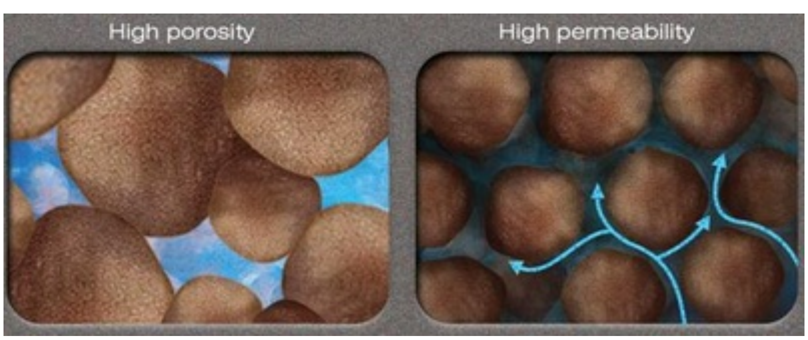
Introduction

Oil and gas are held underground in sedimentary rock formations and can be extracted through many different methods. Conventional drilling extracts "easy to reach" oil and gas, which flows to the surface through a vertical well. Unconventional drilling techniques, or drilling horizontal wells and the process of hydraulic fracturing, are used to extract trapped oil and gas from geological formations. See the illustration below that compares drilling techniques to desserts.



Drilling into conventional sources is like sticking a straw in a jelly donut – the petroleum is trapped in a large single formation that just flows out under pressure. Drilling into unconventional sources like oil and gas shale is quite different, more like tiramisu – the petroleum is in many layers that have to be individually tapped using horizontal drilling and fracking methods to open up the rock. Saudi Arabia has a bunch of really big jelly donuts. The United States has lots of tiramisu, plus some pretty good jelly donuts as well. Source: Jim Scherrer

Sedimentary rocks have the ability to hold oil, natural gas, and water due to physical properties called porosity and permeability. Porosity refers to the tiny air spaces in the rock itself. Permeability is a measure of the ability a rock to allow water, oil, natural gas, or other fluids to pass through it. In other words porosity is the rock's ability to hold a fluid and permeability is the rock's allowance or resistance to flow of a fluid through it.



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Experiment

Purpose

Demonstrate how different types of rock absorb water and how this relates to where we find oil and gas.

Problem

Which type of rock will hold the most water after being submerged in water for several days? How does this relate to the rock's porosity?

Hypothesis

Ask students to write an "If, then" statement relating back to problem.

Procedure

1. Weigh each sample and record the weight in the Raw Data Table provided.
2. Find the volume of your rock sample using water displacement method.
3. Record the volume of each sample in the Raw Data Table.
4. Dry off each sample after finding the volume.
5. Fill the 250mL beaker with 200mL of water.
6. Place each sample in beaker and leave it submerged in the water for 10 minutes.
7. After 10 minutes remove the rock sample, shake or dab off any excess water, and weigh and record the weight in the data table.
8. Place the sample back in beaker and repeat every 10 minutes for the remainder of the class period.
9. After the last measurement, cover each beaker with plastic wrap and leave them on counter.
10. Take weight measurements again after a 24-hour period and record.
11. Place the samples back on counter and repeat measurements daily for three days.

Analysis

Once students have completed their Raw Data Table, ask them to complete the Processed Data Table. Ask students to graph their results.

Conclusion Questions

1. Which rock had the highest porosity (% of water absorbed)?
2. Which type of rock has the potential to hold the most water, gas or oil? Explain.
3. In which type of rock would you expect to find an aquifer? Why?
4. If you were looking for a rock formation to hydraulically fracture for oil and gas, which formation would you choose and why? Choose between granite, sandstone, or shale.

5. Explain the importance of the cement casing used during fracking and relate this to porosity.

Conclusion
Ask students to revisit their hypothesis, discuss their results, address the strengths and weaknesses of the experiment, and list two suggestions for further experiments or research.

Teacher Notes
Do not use chalkboard chalk for this experiment, it dissolves too quickly. Magnesium carbonate is gym chalk and can be purchased at sports supply stores (or if you have a gymnastics team, maybe you can borrow some from them). A 1lb box will be adequate for several experiments.

Pieces of sample rock need to be small enough to fit into a large (500mL) graduated cylinder. You may need a hammer to break samples into small enough pieces or use samples from a rock sample kit.

You can use other types of rock samples such as scoria or basalt. Just be sure to use a piece of shale and sandstone to represent the actual rock formations associated with oil and gas drilling.

Extension
Repeat this experiment with oil, remembering that oil is less dense than water and so will occupy more space than the water.

Raw Data Table

Rock sample masses (grams) before and after being placed in water for up to 72 hrs (3 days).

Rock Type	Initial Volume (mL)	Initial Mass	Mass measurement after…							Overall Change in Mass
			10 min.	20 min.	30 min.	40 min.	24 hours	48 hours	72 hours	
Marble										
Chalk										
Pumic										
Sandstone										
Shale										
Granite										

Note: Water's density is = 1g/mL therefore, water has a unique relationship between its mass and volume: 1 gram = 1cc = 1mL .

Processed Data Table

Volume (mL) of water absorbed by rock samples over a 3 day period

Rock Type	Total Volume of Water Absorbed	Volume of Rock	Percent of Water Absorbed
Marble			
Chalk			
Pumic			
Sandstone			
Shale			
Granite			

Calculations: To find the percentage of water absorbed by each sample we need to know the overall change in mass of the rock sample. This change in mass relates to the amount of water or volume of water absorbed by the rock.

Use the following formula:

$$\frac{\text{Volume of water absorbed (mL)= overall change in mass}}{\text{Volume of rock sample (mL)}} = \text{\% of water absorbed}$$

Example: Water absorbed was 3mL and volume of sample was 25mL

$$\frac{3\text{ mL}}{25\text{mL}} = 0.12 \times 100 = 12\%$$

Make a Fracking Model

Introduction
Students will design a model to demonstrate how hydraulic fracturing aids in extracting oil and gas from shale deposits thousands of feet beneath the Earth's surface.

Credits
Activity developed by UCAR AirWaterGas Teachers-in-Residence Shelly Grandell, Tori Hellman, and Rebecca Bradford.

This activity is modified from the NEED Project Fracturing With Gelatin Activity, found in the [Wonders of Oil and Gas Unit].

Grade level
6-12

Time Required
Class Time: 1 block period ~100 minutes or two 50-minute class periods

Learning Goal: *Students will understand that horizontal drilling allows for more surface area of host rocks to be fracked after designing a model that demonstrates hydraulic fracturing methods.*

Lesson Format: Hands-on activity

Next Generation Science Standards
MS ESS3.A Natural Resources*: Humans depend on Earth's land, ocean, atmosphere and biosphere for different resources, many of which are limited or not renewable. Resources are distributed unevenly around the planet as a result of past geologic processes.*
HS-ESS3-1 *Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity. ESS3.A*
HS-ESS3-2 *Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios. ESS3.A, ETS1.B*
HS-ESS3-4 *Evaluate or refine a technological solution that reduces impacts of human activities on natural systems ETS1.B, ESS3.C*

Materials for 10 groups
- 40 packets of gelatin (Knox Gelatin works well.)
- Ten 20 oz, clear, plastic bottles, rinsed
- One box of Plaster of Paris
- Ten cups
- Ten spoons
- Water
- Ten binder clips (or paper clips)
- Ten veterinary catheter tubes (size 10-14 French)
- Ten Leur lock syringes (that are the same size as the catheter tubes)
- Ten large straws that catheter tube will thread through

Preparation

1.) *Collect empty plastic water/soda bottles well before lab (have students bring in bottles at least a few days before the lab).*
2.) *Make the gelatin at least one day before (use 1:4 ratio for more stable gelatin), and pour into the plastic bottles. Cool the gelatin in a refrigerator overnight.*
3.) *In class, before students begin, mix plaster. Make the plaster right before you plan on using it, as plaster hardens quickly. Distribute it to students in the cups.*

Introduction

Show students a picture of a stratigraphic column that contains a deep, tight, oil and gas bearing shale. Ask students to come up with ideas as to how they might access this deposit. Tell them that they may only make a 10-12 inch hole on the ground surface to reach the deposit.

Here is an example from the Oklahoma area: (students would need to access the red and green beds)

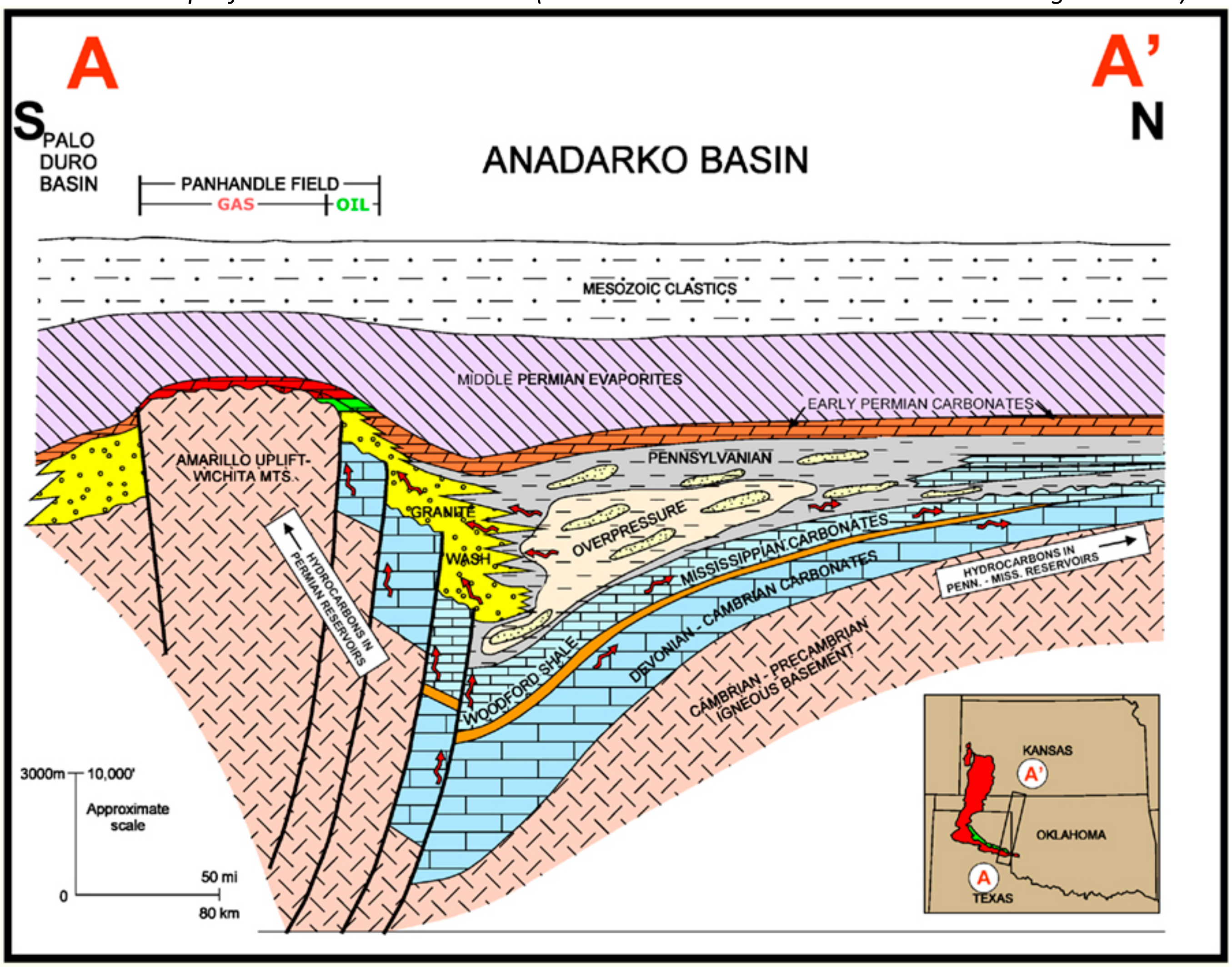

Image from: Fierstien, John. The Anadarko Basin Makes Oklahoma Oil & Gas More Than OK. Drillinginfo, 9 Dec. 2014. Web. 13 Nov. 2015. <http://info.drillinginfo.com/>

Students will have a variety of answers. Lead the discussion into surface area by asking: How can we access the oil and gas bearing formation beyond the area reached with a vertical well? In oil and gas terminology, traditional drilling technology using vertical wells is called conventional oil and gas extraction.

Directions

- Pass out materials to groups.
- Instruct students to assemble the catheter apparatus

Catheter Assembly:

- Attach open end of catheter tubing to a syringe
- Use paper clip or binder clip to pinch bottom of tube ABOVE holes, this will prevent fluid from leaking before injection (see Figure 1).

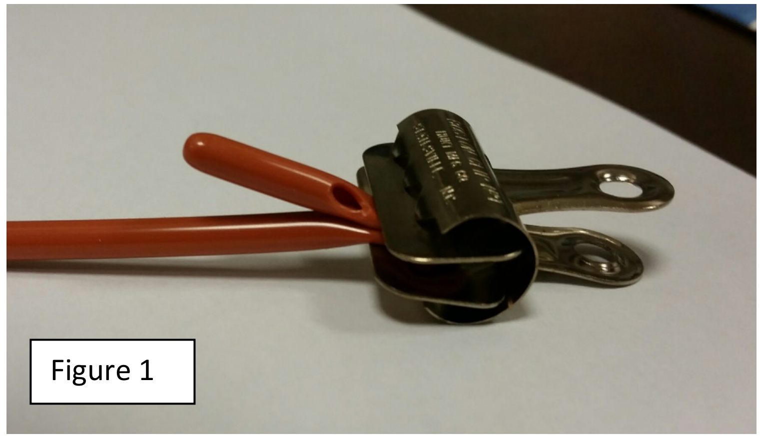

Figure 1

Procedure:

1. Take bottle with gelatin and lay on side. Tell students that the gelatin in the bottle represents a horizontal layer of rock that contains fossil fuels.
2. Insert the straw to bore a hole about two thirds of the way through the gelatin. DO NOT GO ALL THE WAY TO BOTTOMOF THE BOTTLE! (see Figure 2) Tell students that this is analogous to horizontal drilling in which a well is drilled from the surface down and then the drill bit is turned to drill through the rock layer.

Figure 2

3. Place thumb over end of straw, pull out slowly, and making sure to extract the gelatin core completely. This is the most difficult step. If there is not enough suction the gelatin core may not come out of the bottle completely, and the experiment won't work if the bore hole is blocked. Tip: You can apply suction with your mouth on the straw to extract the core as well.
4. After clearing the straw, reuse the straw from step 3, and place it into the bore hole, (you will need to hold onto the straw during injection of fluid (see Figure 2)). This straw will serve as the well casing.
5. Using the fracking catheter assembly already constructed, fill the syringe full with the plaster mixture (ie. fracking fluid) while it is attached to the catheter tube, allowing the mixture to fill the tubing until both the syringe and tube are full. Tell students that the plaster is a good representation of fracking fluid because it is granular and the grains represent the sand (proppant) in real fracking fluid.

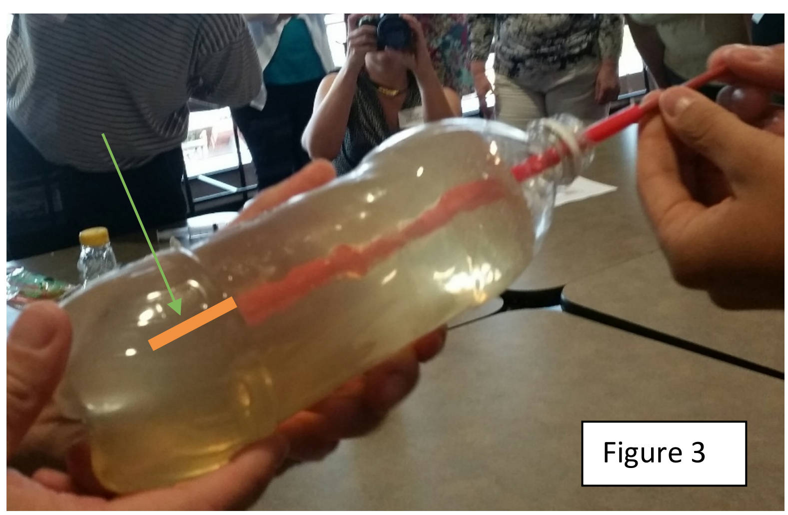

Figure 3

6. Carefully put the plunger back into the syringe, without pushing the fracking fluid out.
7. Remove the binder clip and insert the catheter tubing into the straw, or well casing, until the tube extends past the borehole straw approximately 3 cm. into the gelatin (see Figure 3).
8. Using very firm, steady pressure, push the plunger to inject the plaster into the gelatin.
9. Observe the fracturing pattern of the gelatin.
10. Pull the tubing out of the gelatin carefully, trying not to disturb the fractures.
11. If desired, you can allow the gelatin and plaster to sit until the plaster hardens, and you can then extract the plaster cast of fracture pattern to make further observations by cutting the plastic bottle away and discarding the gelatin.

Assessment
Students should sketch and label their model and demonstrate an understanding of the relationship between the model and what a real hydraulic fracturing process would look like.

Assessment Questions students could be asked:

1. Why did you have to apply pressure to fracking fluid to create fracture patterns?
2. How does this model represent hydraulic fracturing?
3. How does this model NOT represent hydraulic fracturing?
4. What improvements could be made to the model to make it more accurate and realistic?
5. How does the plaster simulate fracking fluid?
6. How does the plaster NOT simulate fracking fluid?
7. What does the casing straw represent? What kind of materials would you need to construct casing in the real world? Why?
8. Do you think if you changed the density of the fluid, would the fracture patterns be the same? Why?
9. What is the purpose of the proppant (grains) in the fluid?
10. Why do we hydraulically fracture wells?

Background information:
Access to oil and gas deposits in the U.S have become increasingly accessible through the advent of hydraulic fracturing. Hydraulic fracturing, known as fracking, is the process in which and oil and gas bearing host rock, such as shale, is injected with fracking fluid at high pressures to stimulate flow of hydrocarbons out of the well.

Fracking fluid is a mixture of water with sand and chemicals to aid in flow down the well. Wells used for hydraulic fracturingl can be vertically or horizontally drilled. Horizontal wells begin with an initial wellbore (the vertical component) then the hole is gradually turned about 90 degrees to be oriented horizontally within the oil and gas bearing formation. Horizontal wells can spread out for miles. Some single vertical wells can have multiple "fingers" spreading out in different directions inside the oil and gas bearing formation.

For a more detailed description of the fracking process, visit these sites:
http://www.fracfocus.org/hydraulic-fracturing-process
http://www.usgs.gov/hydraulic_fracturing/
http://www2.epa.gov/hydraulicfracturing

Extensions
Try using different fluids than Plaster of Paris, or vary the density of the Plaster of Paris. Discuss how different mixtures of fracking fluid are used for different wells and types of rock.

Use activity as an inquiry project. Provide the students with all of the materials and have them develop a design to model hydraulic fracturing that minimizes risk to groundwater and surface spills. Have the students defend why their model best represents hydraulic fracturing.

Alternate Procedure & Materials:
If you are unable to find catheter tubing, you can use two straws with different diameters, with one that fits inside the other. Follow the procedure below:

Straw Assembly:
- About 10 millimeters from one end of small straw, use a push pin to poke about ten holes 5 millimeters apart, with five holes on each side in a straight line.
- Use a small piece of duct tape to seal the perforated end of the small straw.
- Use duct tape to attach a syringe to the non-perforated end of the small straw and insure that no leaks are possible.
- Cut one large straw for the borehole/casing in half and set aside.
- Follow the above procedure starting on step 3.